JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA.
FOR THE
PROMOTION OF THE MECHANIC ARTS.

VOL. LXVI.] SEPTEMBER, 1873. No. 3

EDITORIAL.

ITEMS AND NOVELTIES.

The Mills' Portable Engine.—The accompanying engraving illustrates an improved construction of portable engine, manufactured by the American Engine Company, of New York.

The engine is mounted upon wheels, adapting it to use for agricultural purposes, as well as for various other uses where a portable engine may be required.

The following description, condensed from the exhaustive pamphlet issued by the Company, will indicate its important features:

The cylinder, it will be observed, is placed at the upper part of the boiler close to the smoke-stack. It has an ample base with strong flanges, and held to the smoke box by well-fitting turned bolts; both head and nuts can be quickly reached with a common wrench. The smoke-box is an extension of the sheet forming the barrel of the boiler. The bolts attaching the cylinder not being placed in the steam or water space, are thus freed from liability to leakage. In this way, too, it is sought to avoid adding to the strain already within the boiler the strain of the engine when working. Instead of conducting the exhaust through elbows and tortuous passages, the steam makes but one turn, and that through a very easy curve.

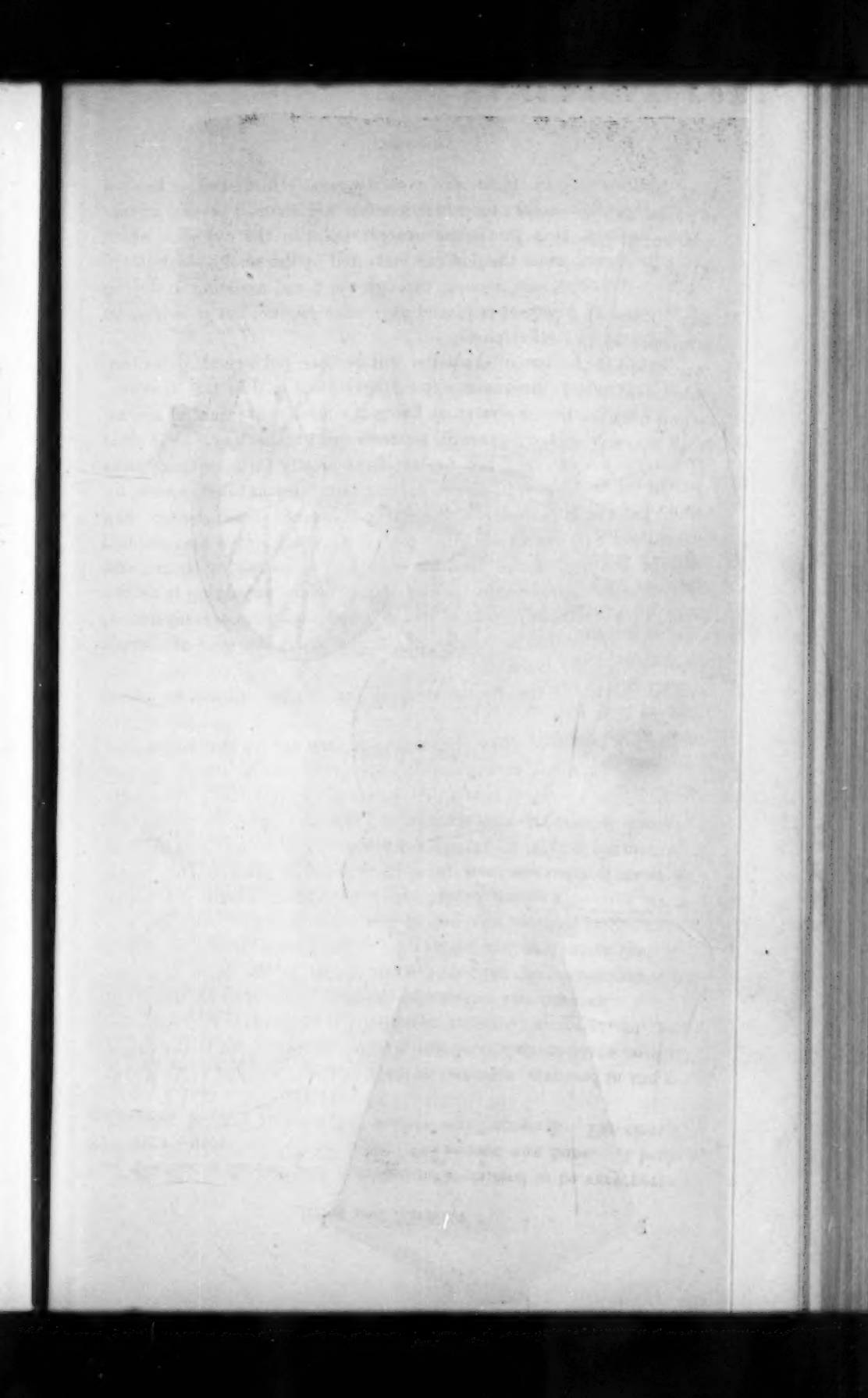
A steam dome of double the capacity usually furnished, is located within the smoke-stack, for which location are claimed several advantages, namely, that this is the nearest point to the cylinder which takes its steam, while the dome is jacketted by the smoke-stack itself, the heated waste gases passing through the dome, assisting in drying the steam. A governor is placed upon each engine, but is hidden on the engraving by other parts.

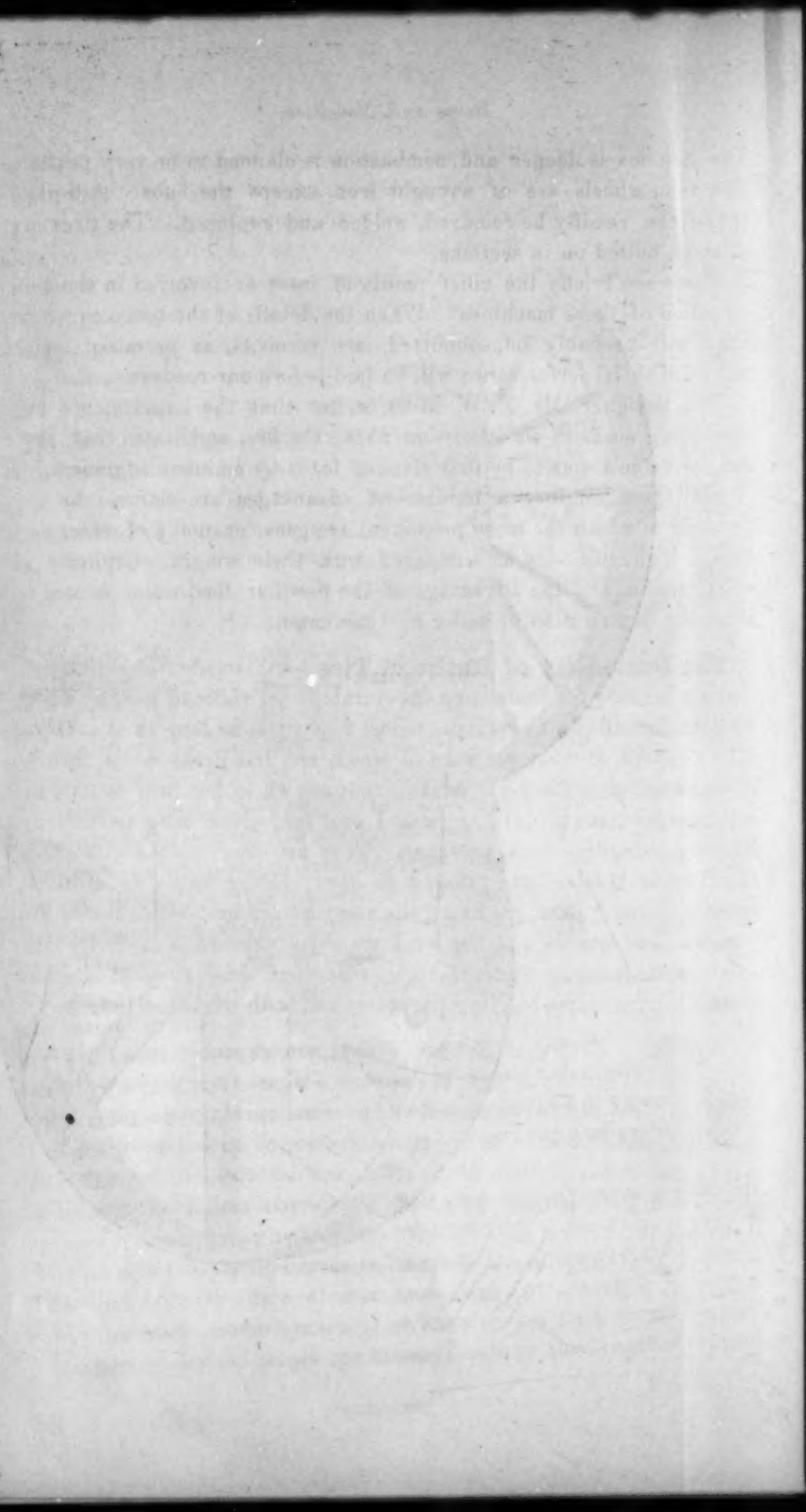
Beneath the bottom of the boiler will be observed a rectangular box, which represents the steam-water heater employed in this construction. This location is chosen as being the most convenient of access, and for putting the apparatus entirely out of the way. The cold feed water, on entering the heater, flows slowly three or four times over its whole length, in direct contact with the exhaust steam, by which process, it is declared, the water is heated much better than when steam only surrounds pipes containing water. It is also claimed that the heating of the feed water nearly to its boiling point, and permitting an appreciable time to elapse before supplying it to the boiler, a considerable portion of its universal impurities are separated, and deposited in the feed-water heater, by which the evils of incrustation are greatly lessened.

A few details of the construction of the engine will not be out of place.

It will be noticed that the engine is very low on the boiler, and this, with its general arrangement, adds greatly to its steadiness and accessibility. The main shaft is of the simplest form, being one single bar, with but one diameter—end to end. The two bearing boxes are cast to the saddle, that is, all in one solid piece, and cannot heat or bind from unequal expansion, nor from getting out of place. The crank wheel is not only forced on the shaft, but is also keyed. A collar for the shaft is made by the hub of the crank wheel on one side, and by the governor pulley on the other. The steam valve eccentric is secured to the back of the crank wheel, enabling the main bearings to be lengthened greatly beyond the usual length. The eccentric rod does not have the usual crook or offset, but is in direct line with the valve. The apparently excessive counter weight opposite the crank pin can scarcely fail to receive attention, but is claimed to be a construction approved by experiment as advantageous.

The shortness of the smoke-stack is also a peculiar feature of the engine, being only two and a half feet high, which is claimed to be sufficient. It will also be noticed that it is provided with ash pans.





The fire box is deeper and combustion is claimed to be very perfect. The road wheels are of wrought iron, except the hubs. A broken spoke can readily be removed, welded and replaced. The tires are of steel, bolted on in sections.

These are briefly the chief points of interest involved in the construction of these machines. When the details of the tests, to which they will probably be submitted, are received, as promised, some notice of their performance will be laid before our readers.

The designer, Mr. E. W. Mills, writes that the experiments are now being made in air admission above the fire, and states that, thus far, its value seems to be that claimed for it by eminent engineers.

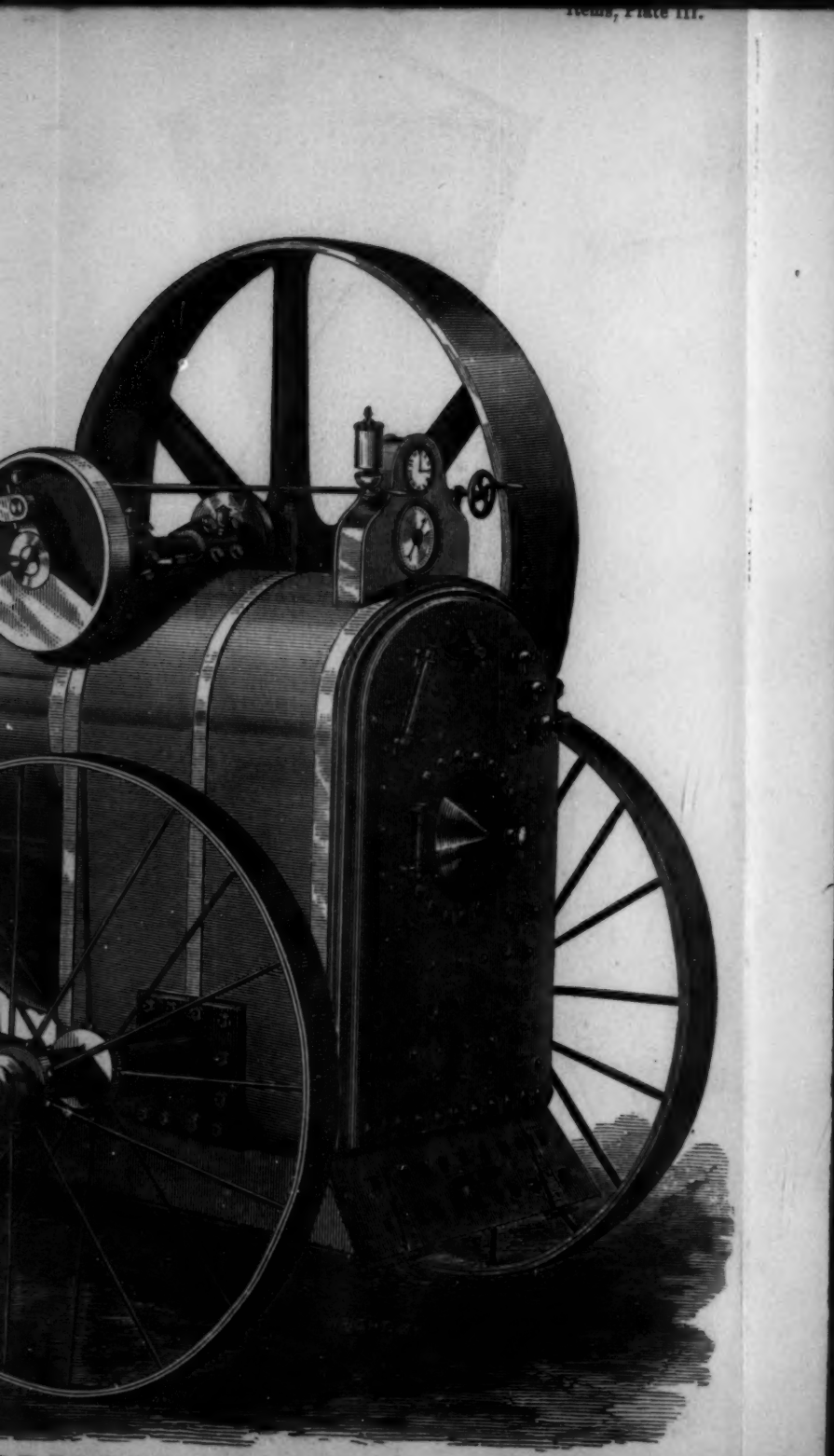
For these engines a number of advantages are claimed by the makers, of which the more prominent are great economy of water and fuel, a high efficiency as compared with their weight, simplicity of construction, and the advantage of the peculiar feed-water heater in reducing incrustation of boiler to a minimum.

The Durability of Railroad Ties.—A Dresden engineer proposes a method for increasing the durability of railroad ties, by which he considers they may be made to last four times as long as at present. The sleepers, of whatever kind of wood, are first dried in air, then in a hot chamber. They are next introduced while hot into an impregnating apparatus containing heated coal tar, where they are impregnated thoroughly under pressure. They are then coated with sifted sand or coal ashes, and allowed to dry. Every fissure is carefully filled; the nails used in fixing the sleepers are first dipped into hot coal tar, and any part of the work which is exposed is carefully covered. The inventor states further that wood thus prepared has also been used for house-building purposes, and with excellent results.

The International Bridge.—It is now expected that the great international railway bridge, to span the Niagara river between Buffalo and Fort Erie, will be completed, and a formal opening take place, some time in October next. It is the enterprise of an independent company, was commenced in May, 1870, and its cost will be something over one million dollars. The Buffalo "Commercial Advertiser" thus describes it:

"The superstructure is of iron, supported on stone piers, with the necessary draws for the passage of vessels. The length of the main bridge, across the river, is 1968 feet; thence across Squaw island to the west end of the bridge over Black Rock harbor, is about 1200

AMERICAN PORTAB



ORTABLE ENGINE.

feet; and the bridge over the harbor to Niagara street is 517 feet. Squaw island is at present crossed by trestle work some twenty feet in height, but this is to be filled up so that the track across the island will be upon a solid embankment. The work of filling will not be done until the completion of the bridge, however, as the material is to be brought from Canada. Commencing at the Canada shore there will be nine spans across the river proper; three of them are 190 feet each in the clear; then come three spans, each 240 feet in the clear; then two draw openings, each 160 feet; then one span of 190 feet to Squaw island. The length of the bridge across Black Rock harbor, as before stated, is 517 feet, and in this will also be two openings of 90 feet each, with a pier between. The 'swing' over this opening, as well as that over the opening of the river, will be operated by steam, and the length of time required to open or shut the same is given at fifty seconds. The location of the swing in the river—nearer the American than the Canadian shore—is in accordance with the decision of a commission of United States engineers, appointed by the government, consisting of General Warren, Colonel Merrill and Col. Harwood, and the selection of the position meets the entire approval of the Canadian parties. Of the piers in the river, eight in number, all are finished save one in about the middle of the stream. In preparing for the foundation of this it was discovered that the rock in the bed of the river was covered to the depth of about nine feet with gravel. This it was, of course, necessary to remove. The work of removal has been finished, and the laying of the foundation will be immediately commenced. It is calculated that the pier will be completed in the course of three or four weeks. All the piers are so laid and built up as to secure the greatest solidity, and offer the least possible resistance to the ice. The depth of the water in the river where the bridge crosses is from ten to forty-three feet. The iron work for the Bridge is manufactured at Phœnixville, near Philadelphia, and the superstructure is known as the Pratt truss. The trusses consist of four main lines—that from pier to pier, the lower chord, as it is called; that parallel with it, but at a considerable height above it, and known as the main chord; and counter supports at either end, on which the upper chord rests. The upper chord and end counters are tubular, put together in five pieces, with flanges. The lower chord consists of rods which tie the counters and verticals, and resist the tendency of the upper chords to thrust the counters apart. The upper chord is that on which the roadway is hung. Transverse girders are suspended

therefrom. The girders are bolted to the lower chord and connected with the upper by an iron vertical principal. The uniform load which would necessarily fall on this vertical principal is distributed laterally by means of counterbraces and rods, until it is thrown finally on the piers. The bridge has the strength of a tubular one, without its weight and other objections. Vertical and counterpieces form the sides; the tops of the vertical principals, united horizontally, strengthened diagonally, and supported by angle ties, form the roof, and the road way constitutes the floor. A novel plan is pursued in placing the iron spans upon the piers. They are built upon a frame-work over a number of pontoons, which act in the manner of a dry dock. The pontoons are carefully dropped between the piers, and when in position water is let into them, and the iron truss is settled into its exact place on the piers."

The chief engineer in the construction of the bridge is Mr. E. P. Hanaford, of Montreal, and the resident engineer is Mr. J. Hobson, of Fort Erie. The Grand Trunk, Great Western, and Canada Southern railways have already put down approaches to the bridge on the Canada side. The approach on this side is about 100 feet south of Parrish street, and here, also, several of the roads have already put down tracks, including the contemplated New York, West Shore and Chicago road.

A New Engineering Project.—A project of very novel character has lately been proposed by Captain Boudaire, and discussed before the French Geographical Society. It is nothing else than a proposition to create an interior sea in the desert of Sahara. A geodesic levelling made by the officer named, and calculations made on the differences of the levels as ascertained, have given promising results. The bed of the Mel-Rhir, a kind of salt marsh which covers a large extent of land in the province of Constantine, is nearly 27 meters below the level of the Mediterranean Sea. On its western side this bed inclines towards the east, having an inclination of 20 to 25 meters per kilometre; so that at 4 or 5 kilometres from its shore, the level is 28 metres below that of the sea. No serious elevation has been found between the series of lagoons, which extend far beyond the Tunisian frontier. The Geographical Society has called the attention of the government of Tunis to these results, asking to have a survey made between the Gulf of Gabes and Lake Faraoun, which terminates the series of interior lakes. If, as ap-

pears probable, this survey takes place, and if it establishes the fact that this lake is situated below the level of the Mediterranean, the possibility of creating an interior sea by the aid of a canal between the Gulf of Gabes and Lake Faraoun would be demonstrated.

Coal-Cutting Machinery in the United States.—An American coal-cutting machine, which has been for some time in operation in the Coal Brook Mines, near Brazil, Indiana, is described as follows:

It consists of a five-horse-power engine, worked by steam carried into the mine through an iron pipe, terminating in a few feet of rubber hose, and permits of the full motion of the machine. The design is to employ compressed air in place of steam as soon as the experiments are completed. The cutting arrangement is an iron rim, of four feet in diameter, which has on its periphery movable steel teeth, placed at points about twelve inches apart. These teeth can be removed and sharpened when they become dull. This rim lies on small wheels, which support it and allow a free motion, and has cogs on its under surface, which work into cogs on a shaft turned by the engine. By this means the power is applied near the circumference of the wheel, instead of at the centre, as in the ordinary circular saw. The principal reason for this arrangement is to get a deeper cut in the coal. The cutter can be put to a depth of three feet and a half, or seven-eighths of its whole diameter, whereas the ordinary saw can cut barely to one-half its diameter.

The machine runs on a movable track, and is fed by a screw working in cogs. The track is put down along the side of the coal, at a proper distance from it, and when a cut has been made the whole length, the machine is put on trucks and wheeled to the next room, where the track laying and cutting is repeated.

Its operation is spoken of as being in every way successful.

A New Tunnel Enterprise.—A tunnel is projected beneath the river Humber, in England, which shall be 2840 yards long. It will begin at Hessle, on one side of the river, and will terminate at Barton, in North Lincolnshire.

The Hoosac Tunnel.*—A contemporary reports the status of the work upon the tunnel for the month of July to be as follows: East end section completed December 12th, 1873; central section,

* Scientific American.

heading advanced westward, 151 feet; west end section, heading advanced eastward, 137 feet. Total advance of headings during the month, 288 feet. Length opened from east end westward, 14,235 feet; length opened from west end eastward, 9,677 feet. Total lengths opened to August 1, 1873, 23,912 feet. Length remaining to be opened August 1, 1873, 1,119 feet.

The American District Telegraph Company.—At the last meeting of the Franklin Institute there was described, and exhibited in operation, a system of telegraphing now about being introduced into Philadelphia, which, from its very great convenience, bids fair to become a decided favorite amongst business men, as well as to serve many useful purposes in the household.

The Hon. Daniel M. Fox, ex-Mayor of Philadelphia, introduced the subject to the attention of the members of the Institute, giving briefly a history of the gradual extension of the art of telegraphy to constantly increasing usefulness, and then explained the district system of telegraphy as follows:

This small iron box (showing it) contains a simple train of clock-work, which, when released and allowed to run, causes a small wheel, called a circuit wheel, to revolve, and when connected by wires with a battery and suitable apparatus, breaks and closes the electrical circuit a certain number of times, regulated by teeth cut in the wheel, thus indicating a certain fixed number. The wheels being different in numbers of teeth or notches, of course different numbers are communicated, and you readily see how invaluable this little box becomes.

As utilized by the American District Telegraph, the calls are given for a messenger, an officer or the Fire Department.

To explain more fully, the city is laid out into districts of about sixteen squares each. Near the centre of each district is located an office, from which wires radiate and are conducted to all parts of the district, running in and out of dwelling-houses, public buildings, stores, offices, factories, etc. The signal-boxes are connected with these wires, and in the district office the wires are connected with galvanic batteries, call-bells and self-starting Morse registers. The instant one of these boxes is operated upon, by merely pulling the ring projecting beneath, the circuit-wheel is allowed to revolve once, and its number is rung upon the call-bell, and recorded upon the strip of paper set in motion by the self-starting Morse register in the district office. The operator at once dispatches a messenger boy to answer the call. If the ring is pulled three times it indicates that an officer is wanted, and one is sent at once, accompanied by a messenger; if the ring is pulled more than three times in succession, fire is indicated, and the officer answers the summons with a fire-extinguisher, and the alarm is instantly communicated to the central office of the City Police and Fire Alarm Telegraph, and also the several fire engine and hose houses.

Thus it will be seen that electricity is to be reduced from its proud position as a messenger between continents to the humble uses of domestic life.

It is to be made an errand boy, to answer every household call.

There are thousands of little services which persons in moderate circumstances would gladly pay for at the rates charged by the Company, who cannot afford or do not desire to keep an errand boy or male house servant.

The American District Telegraph Company proposes to perform the messenger service indispensable among business men in a manner so thorough, expeditious, and cheap that the most entire satisfaction shall be given subscribers. A lawyer, banker or broker desiring to communicate with his client, or customer, touches the telegraphic key and instantly summons a trusty and swift footed messenger. A client at the office of his solicitor or financial agent, requires the services of a reliable person to bring or to carry valuable papers, or to perform any one of the thousand services which in a great city are in constant requisition. The telegraph places at his command and at moderate charge the trained servants of a responsible corporation whose interest it is that its patrons should be promptly and faithfully served.

A tradesman wishes to forward to his customer any article furnished, the telegraph permits him to do so without any inconvenience, thus oftentimes enabling him to effect sales because of the ability to promptly deliver goods purchased, which otherwise would have remained unsold. Thus the telegraph tends to increase trade, because it makes it easier of transaction by placing a supplementary corps of messengers at the disposal of both trader and customer, to do the bidding of either.

Physicians can avail themselves of it on communicating to their patients, sending medicines and procuring nurses.

Hotel keepers find that it not only saves an extra errand boy, but is also a great convenience to their guests.

A special feature of this system is to protect against burglary or fire. If a housekeeper is disturbed in the night by a noise of burglars in his house, he merely pulls the ring, and one or more policemen will arrive before the burglars have time to effect an entrance.

If your house is left vacant during the coming season, burglar attachments can be made with the instrument, and everything so arranged that the opening of a door or window is made known at once at the district office. A fire is discovered in the house; the alarm is at once given by pulling the ring as directed, and almost as soon as a bucket of water can be obtained in the house, men appear at the door armed with fire-extinguishers, accompanied by messengers, and in many cases will have extinguished the fire before the arrival of the fire department, which has also been summoned by the same agency.

In fact, there is no end to the use and convenience of our universal friend.

At the conclusion of Mr. Fox's remarks, a practical exhibition of the District Telegraph system was given, to the great interest of the members. Batteries and alarm boxes, with wires connected with the District office at Seventh and Chestnut streets, were put in the lecture room.

A signal was sounded for a messenger, and in about one minute a lad, dressed in uniform, rushed into the room with paper and pencil in hand, ready to deliver any message. A signal was then given for an officer, and also in a minute a conservator of the peace was in the midst of the audience, ready for duty. A fire alarm was then given, and in one minute's time appeared a man with a fire annihilator strapped on his back, ready to go into service.

These parties all came from the District office at Seventh and Chestnut streets, and did not leave there until they were summoned by the alarm-box, operated on by the speaker.

To Distinguish the Iodide of Silver from the Chloride, or from Embolite.—By JOHN C. TRAUTWINE, Civ. Eng.—The chloride of silver (alias horn-silver or cerargyrite) and also embolite are frequently mistaken by miners and others for the iodide of silver, alias iodyrite. Although in physical characters these minerals bear at times a considerable resemblance to each other, yet it is easy to detect the iodyrite by the following simple process, accidentally *stumbled upon* by myself: Mix a few drops of nitric and muriatic acids, and drop in a fragment of the suspected mineral. If it is iodyrite it will almost instantly lose its yellow color and its lustre, and become first brown and then black. Then it will again become yellow, and will be opaque, resembling a piece of yellow ochre. If the fragment is very small, say less than the head of a pin, or if in powder, these changes will take place within two or three minutes. If larger, a somewhat longer time will be required, and the acid close around the specimen will become slightly tinged with a delicate straw color. No such effects, nor, indeed, any appreciable others, are produced on either cerargyrite or embolite. The iodyrite does not dissolve in the mixed acids. Compared to cerargyrite, the iodyrite is a very rare mineral; and the former, when of a yellowish color, is sometimes sold to collectors for the latter, at high prices.

Mineralogical.—Some confusion has arisen in the designation of the two species, Amblygonite and Montebrasite, but the distinction has been clearly established by Descloiseau. In 1862 a mineral was discovered at Hebron, Maine, and referred to the species Amblygonite; in 1872 a mineral was found at Montebras, in France, and named Montebrasite. It has since transpired that the original mineral from Montebras is merely Amblygonite; but a second species has been found in this locality, to which the name of Montebrasite has

been transferred, and it is now proved that the so-called Amblygonite from Hebron is really this true Montebrasite.

The matter, therefore, stands thus: Two minerals are found at Montebras, one called Montebrasite, the other Amblygonite; the former is also found at Hebron, in Maine, and the latter occurs also at Penig, in Saxony. Montebrasite contains lithia, but no soda, and also contains a notable proportion of water. Amblygonite contains both soda and lithia, but no water.

The Preservation of Iron Ships.*—By JAMES YOUNG.—My attention was called in January, last year, to the rusting of iron vessels, by observing that the bilge water of my yacht (the *Myanza*, 214 tons) was much discolored by red oxide of iron. Knowing that bilge water is apt to become acid, and thus to attack iron, the result was easily accounted for. Even when the water does not become acid we may expect some action on the iron to take place, when sulphuretted hydrogen exists there, as it frequently does. In this case, first a sulphide, then an oxide, and some sulphate are formed. The remedy seemed to be easy, because this acid can be neutralized by lime. The presence of this earth would also prevent the formation of sulphuretted hydrogen.

I put this immediately into practice, adding lime until the bilge water was alkaline, and samples were taken every fourteen days, which showed the amount of rust to be rapidly diminishing. After six months the liquid became perfectly clear, so that the cure was complete. The yacht is a composite one, and the action is therefore greater than in iron vessels generally, because of the copper bolts which are used. These bolts cause galvanic currents with the iron, and greatly assist its oxidation and solution.

As very little lime will last a long time, the plan causes neither trouble nor expense. * * * * * *

The Bed of the Atlantic Ocean.—Thompson sums up the general results of the Atlantic soundings as follows: "In the Arctic Sea there is deep water, reaching to 9000 feet, to the west and south-west of Spitzbergen. Extending from the coast of Norway, and including Iceland, the Faröe Islands, Shetland and Orkney, Great Britain and Ireland, and the bed of the North Sea to the coast of France, there is a wide plateau on which the depth rarely reaches 3000 feet;

* Iron.

but to the west of Iceland, and communicating doubtless with the deep water in the Spitzbergen Sea, a trough 500 miles wide, and in some places nearly 12,000 feet deep, curves along the east coast of Greenland. This is the path of one of the great Arctic return currents. After sloping gradually to a depth of 3000 feet to the westward of the coast of Ireland, in latitude 52°, the bottom suddenly dips to 10,000 feet at the rate of about 15 to 19 feet in the 100, and from this point to within some 200 miles of the coast of Newfoundland, when it begins to shoal again, there is a vast undulating submarine plain, averaging about 12,000 feet in depth below the surface—the telegraphic plateau. A valley about 500 miles wide, and with a mean depth of 15,000 feet, stretches from off the south-west coast of Ireland, along the coast of Europe, dipping into the Bay of Biscay, past the Strait of Gibraltar, and along the west coast of Africa. Opposite to the Cape de Verde Islands it seems to merge into a slightly deeper trough, which occupies the axis of the South Atlantic, and passes into the Antarctic Sea. A nearly similar valley curves round the coast of North America, and 12,000 feet in depth off Newfoundland and Labrador, and becoming considerably deeper to the southward, where it follows the outline of the coast of the States and the Bahamas and Windward Islands, and finally joins the central trough of the South Atlantic off the coast of Brazil, with a depth of 15,000 feet.

Dynamite.—From "Iron," we condense the following statement of the action of this explosive under various conditions, which throws some light upon the subject.

When dynamite is ignited by violent concussion, such as that occasioned by the detonation of a strong primer, it explodes, even in the open air, and if confined produces so great an effect that one part of nitroglycerin does the duty of ten parts of gunpowder. If inflamed in any other manner, without percussion, it burns quietly in the open air, and if confined may give rise to an explosion.

This explosion, however, whatever may be the temperature and the pressure to which the charge is submitted, is of a quite different character from the one above mentioned, its force being about twice that of gunpowder.

Hardening Steel.—Watch and clock makers and engravers harden their steel in sealing-wax. The article is made white hot and thrust into sealing-wax, allowed to remain a second, then withdrawn,

and again inserted in another part, and this treatment is continued until the steel is cold and will no more enter the wax.

The hardness thus attained is extreme, and is comparable to that of the diamond; in fact, steel hardened by other processes may be engraved or bored with it, the engraving or boring tool being previously moistened with oil of turpentine.

Gilding Iron.—Sodium amalgam is said to be advantageous as a means of simplifying the method of dry gilding iron, and for painting gold designs thereon.

By simply rubbing with the amalgam, the surfaces of iron and similar metals, although oxidized, are at once amalgamated. Some solution of chloride of gold is then applied quickly on the amalgamated surface, and the mercury volatilized by the heat of a lamp or fire. A very uniform gilding is thus obtained, admitting of high polish. With silver and platinum salts similar results are obtained.

Chloroform in Analysis.—It appears that chloroform affords an excellent solvent and means of separation for many vegetable poisons, and hence is highly valuable in chemico-legal investigations.

For example: by shaking the solution, first made alkaline, with chloroform in the cold, the following are quickly and completely extracted: strychnine, quinine, quinidine, cinchonine, caffeine, theobromine, emetine, atropine, hyoscyamine, aconitine, veratrine, narcotine, codeine, nicotine and conine. More slowly are brucine, colchicine and papaverine taken up from alkaline solution; with the aid of heat sabadilline, and in small quantity narceine. Picrotoxine goes over to the chloroform far more easily from acid than from alkaline solution. Neither morphine nor solanine is taken up by chloroform. By shaking the alkaline chloroform solutions of the above bodies with dilute acids, the bodies themselves are obtained pure, leaving behind any fatty or foreign bodies in the chloroform. It is worthy of notice that a systematic process of separating these organic poisons, based upon these facts, has been devised.

An Improved Giant Powder.*—A new modification of dynamite, which has recently been patented by Mr. E. Judson, has the following constitution by weight:

Forty parts of nitrate of soda, six parts of rosin, six parts of sulphur, eight parts of infusorial earth and forty parts of nitro-glycerin.

* Am. Artisan.

The nitrate of soda, rosin, sulphur and infusorial earth are separately dried and pulverized, and thoroughly mixed before adding the nitro-glycerin. Upon adding the nitro-glycerin, it is thoroughly stirred into the dry mixture until it is absorbed, forming a powder of uniform consistency.

It is claimed that this powder is more powerful than the mixture of nitro-glycerin and infusorial earth, the addition of the nitrate, rosin and sulphur increasing its explosive energy. It is further claimed that the only method of exploding it is by the use of detonating substances like fulminate of mercury, and that contact with a flame or concussion will not explode it.

Crystallographic.—The *Neues Jahrbuch für Mineralogie*, contains a paper from Prof. Vom Rath, of Bonn, upon some results of his studies with the crystals of the mineral leucite.

Every student of mineralogy is familiar with the beautiful icositetrahedral crystals of this mineral, which occur so plentifully in the lavas of Vesuvius; and crystallographers have universally been accustomed to look upon them as characteristically isometric (monometric); so characteristic, indeed, that in the nomenclature of Haidinger, the icositetrahedron is called the leucitoid. Prof. Vom Rath has, however, been led, by a study of the direction of certain striæ on the trapezoidal faces of certain of these crystals, to the conclusion that they were not merely superficial markings, but really the edges of twin lamellæ, and as a result announces that the mineral must be transferred from the isometric to the dimetric system.

He asserts that the common crystals of leucite is really a combination of the 16 faces of the di-tetragonal pyramid, with the 8 faces of a primitive octahedron above and below these pyramidal faces. According to this view, the leucite is brought within the characteristic group of Vesuvius minerals crystallizing in the dimetric system, including zircon, humboldtilite, vesuvian, sarcolite, etc.

The Champlain Marbles.—The western part of Vermont, though comparatively small yet in extent, bids fair to possess the most extensive and beautiful, as well as the finest qualities and most valued varieties of marble of any part of the American continent. Its variety of color seems to be limitless, ranging from beds of pure white, through every conceivable intermediate shade or combination, to jet black.

These marbles, though known to exist for a number of years, have

only lately been quarried, and something of their real extent and value made known. At present there are two quarries opened, one upon the shore of Lake Champlain, the other upon an island in the lake. The former covers an area of about 120 acres, the latter about three acres, and, from accurate examination, appear to be entire deposits of the richest variegated marble, of the closest and finest texture, susceptible of high polish, and admirably adapted for decorative architectural and other purposes. The facilities for transporting the marbles are excellent, and the demand for them is steadily growing.

The State Geologist, Prof. E. Hitchcock, speaks highly of the durability of these marbles, remarking that blocks of it taken from the naked ledge and sawed are found to be perfectly sound and unaffected by their long exposure.

This superb natural production must rapidly become famous the world over as an unsurpassed stone for ornamental and decorative purposes, and it has already been largely employed in these directions.

Test for Potable Water.—Good water should be free from color, unpleasant odor and taste, and should quickly afford a good lather with a small proportion of soap. If half a pint of the water be placed in a perfectly clean, colorless glass-stoppered bottle, a few grains of the best white lump sugar added, and the bottle freely exposed to the daylight in the windows of a warm room, the liquid should not become turbid even after exposure for a week or ten days. If the water becomes turbid, it is open to grave suspicion to sewage contamination, but if it remains clear it is almost certainly safe.

Recent Oil Discoveries.—Within the past few days discoveries of an unusually rich character have been made in the neighborhood of Titusville, Pa.

Quite a number of wells have been opened, producing from 600 to 1300 barrels der day. Well informed judges estimate the production of the new region at 30,000 barrels per day. So prodigious has been the flow, that, so it has been reported, the proprietors have scarcely been able to catch the liquid as it flowed from the pipes, and considerable quantities of oil have gone to waste.

Phosphor-Bronze.—The employment of phosphor-bronze for useful purposes in the mechanic arts seems to be slowly extending, though in the construction of ordnance it has not proved to be as satisfactory as was expected.

In France it has been employed by one house ever since its first production, three years ago, for the bearings of plate and general rolling mills.

The engine that drives the rolling mills in which it is used is about two hundred horse power, and the speed about sixty revolutions per minute. The rollers are 6.23 feet long and 2.03 feet in diameter, and weigh five tons. It was found that the gears, made of hard cast iron, broke frequently. These were at first replaced by ordinary bronze, then finally by phosphor-bronze.

The life of the ordinary bronze wheels did not exceed on an average five months, while those made of phosphor-bronze last about nine months.

When applied to bearings, the latter alloy is found to be equally superior to the former.

Editorial Correspondence.

NOTES FROM THE VIENNA UNIVERSAL EXPOSITION.

(From our Special Correspondent.)

Before I enter upon my descriptive report upon the technical, mechanical and other matters of importance connected with the Exposition, I find it necessary to call attention to the very greatly altered appearance of the plan of the several parts of the buildings and surroundings.

In consequence of the wonderful expansion attained by the Exposition, it has been found necessary not only to erect a great number of independent exhibition buildings and additions, but also to cover the greater portion of the courts or spaces between the cross galleries of the Industrial Palace, and employ the space thus economized to the purposes of the Exposition.

On this account, it has heretofore been impossible to obtain an accurate plan of the exhibition, and though the one published with a former report was at the time correct, it has long since ceased to be. It is therefore a matter of congratulation that the recent publication of the present plan of the exhibition, from official sources, has obviated this inconvenience.

The following plate is an exact copy of this official plan, in which

the several parts and departments are indicated with numbers or letters.

For convenience in locating the different points of interest, this plan, conformably with the official one, is divided into zones.

The entrances are designated with +, and the spaces occupied by the several nationalities represented, are indicated by letters.

The plan is divided into four zones. Each zone has its own numbering.

For the technologist, the Machinery Hall affords, above everything else, the greatest interest. Of its dimensions I have already given your readers a report, and refer them to what has already been said in this particular.

The arrangements for transmission of motion were designed by the Engineering Bureau of the Exposition, and completed under the special care of Prof. von Grünberg.

The Commission had pledged itself to furnish steam and necessary machinery for transmitting motion, to the exhibitors of machinery.

As the plan of the Commission consisted in affording to each country represented separate arrangements for power, there was built for each country represented a separate boiler house (see the plate), with independent steam pipes; in addition to this each country furnished the necessary motive power to run its machinery, so that now there are in operation from England and Austria, each 4; from Germany, 3; from America, France, Hungary, Russia and Switzerland, each 1 —making in all 17 steam boilers, representing a total capacity of 600 horse-power.

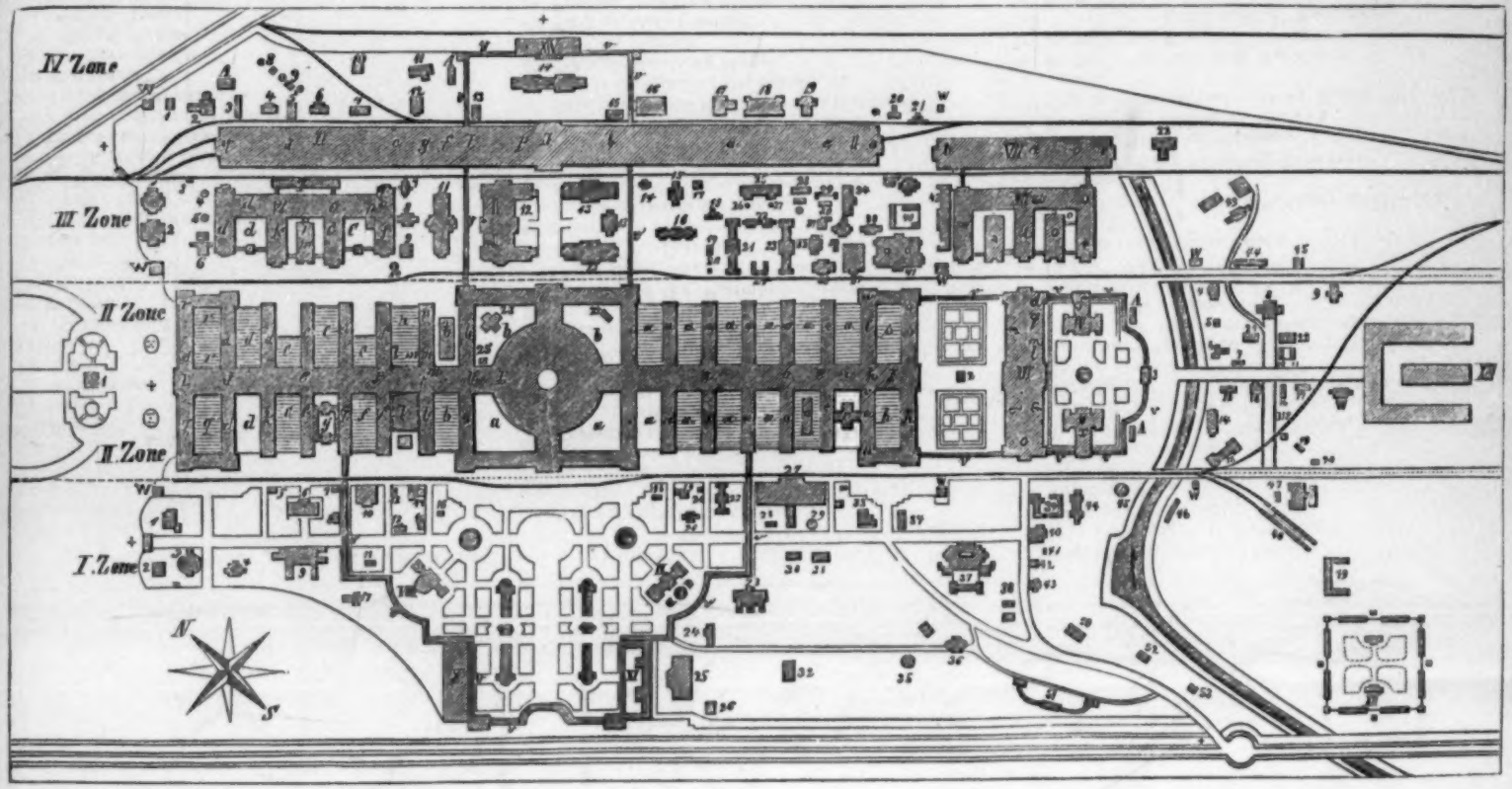
The shafting is not continuous throughout the Hall, but for each nationality is only made long enough to meet the wants of the machinery there in operation.

The boiler houses, of which there are eight in all, were erected at the cost of the authorities; the boilers themselves, however, were supplied by exhibitors. The houses are open, and are furnished with chimneys of sheet iron, 30 meters in height. From the boiler houses the steam pipes pass separately into the Machinery Hall, the main steam-cocks being located where they are convenient of access. The arrangement for the discharge of the exhaust steam, as well as for feeding boilers, is very practical.

In the neighborhood of the Machinery Hall there is located a well-arranged machine and repair shop, which, both during the first arrangements of machinery, as well as at present, performs good service.

Universal Exposition at Vienna, Plate IV.

Journ. Franklin Inst., Vol. LXVI.



DIVISION OF THE SPACE IN THE MAIN EXHIBITION BUILDINGS.

a Austria.
b Germany.
c France.
d England.
e Russia.
f Italy.
g Switzerland.
h Turkey.
i Greece.
k Portugal and Spain.
l Belgium.
m Holland.
n Denmark.
o Hungary.
p Sweden and Norway.
q United States.
r South America.
s China, Japan, Siam.
t Persia and Central Asia.
u Egypt and Central Africa.
v Tunis and Morocco.
w Roumania.
x Northern States.
W Watch Houses.
A Water Closets.
v Covered Passages.

MAIN EXHIBITION BUILDINGS AND ADJUNCTS.

I Industrial Palace with the Rotunda.

17 Boiler House.
18 Kiosk of the Southern Railway.
19 Kühn's Portable Dwelling.
20 Pavilion of the First Austrian Saving Fund.
21 Pavilion of Herr Stork.
22 Pavilion for Little Children
23 Restaurant of the Freres Provençaux (Paris).
24 Sala di Lettura } of Natale Biffi, of Milan.
25 Restaurant }
26 Wine House }
27 Iron Hall—Exhibition Hall for Metal Industry.
28 Pavilion of Austrian Mineral Springs.
29 " for Tobacco and Cigars
30 " of the Perlmose Cement Wares, from the Manufactory of J. Newnüller, in Nussdorf.
31 Russian Restaurant.
32 Steirian Dwelling House.
33 Russian Dwelling House.
34 Exhibition of the Austrian Lloyd.
35 Wigwam.
36 Iron Hothouse of R. P. Wagner.
37 Palace of the Viceroy of Egypt.
38 Small Japanese Buildings and Gardens.
39 Cercle Oriental of Dr. Hardt.
40 Turkish Dwelling House.
41 Turkish Bazaar.
42 Turkish Coffee House.
43 Persian Dwelling House.
44 Exhibition of the Imperial Minister of Marine.
45 Light-house of Saulter & Co., Paris.
46 House of the Photographic Association.
47 do. of the Agricultural Society.
48 Sanitary Pavilion.

5 Stand-pipe for Water Service.
6 Iron House of S. C. Hemming & Co.
7 Swedish Restaurant.
8 Norwegian } Fishing Apparatus.
9 Swedish }
10 Norwegian Garden Kiosk.
11 German Pavilion of Instruction.
12 Germany's " for Industry.
13 German ? Industry Exhibition.
14 Earing House.
15 Pavilion of the Duke of Coburg Gotha.
16 " of Prince Schwarzenberg.
17 " Mauthner.
18 Stable Building of R. Ph. Wagner.
19 Curtis' Obelisk of Cement.
20 Houses of Artificial Stone.
21 Vorderbergen } Mining Industry Exhibition.
22 Innerbergen }
23 Karntner }
24 Pavilion of the Silberegg Brewery.
25 Machine Building Company (Prag).
26 Tar and Asphaltum (J. Bosch).
27 Architectural Ornaments of Zinc (Vinc Wenzel).
28 Steffen's Exhibition of Machinery.
29 Rothschild's Bridge Construction.
30 " Exhibition of Machinery.
31 Slate Exhibition of John Liebig.
32 Wooden Wares (Schubert).
33 Pavilion of the State Railroad.
34 English Restaurant.
35 Pavilion of the Stock Company for Construction of Bridges and Roads.

Division of the Space in the Main Exhibition Buildings.

a Austria.
b Germany.
c France.
d England.
e Russia.
f Italy.
g Switzerland.
h Turkey.
i Greece.
k Portugal and Spain.
l Belgium.
m Holland.
n Denmark.
o Hungary.
p Sweden and Norway.
q United States.
r South America.
s China, Japan, Siam.
t Persia and Central Asia.
u Egypt and Central Africa.
v Tunis and Morocco.
w Roumania.
x Northern States.
W Watch Houses.
A Water Closets.
v Covered Passages.

Main Exhibition Buildings and Adjuncts.

I Industrial Palace with the Rotunda.
II Machinery Hall.
III Fine Art Gallery.
IV " Pavilion.
V Exhibition of Amateurs.
VI Western Agriculture Hall.
VII Eastern "
VIII Pavilion of the Jury.
IX Pavilion of the Emperor.
X Offices of the Exhibition Commission.
XI Post, Telegraph and Tax Offices.
XII Guard Houses.
XIII Buildings for Horse Show.
XIV Depot.
W Watch Houses.
A Water Closets
v Covered Passages.

17 Boiler House.
18 Kiosk of the Southern Railway.
19 Kühn's Portable Dwelling.
20 Pavilion of the First Austrian Saving Fund.
21 Pavilion of Herr Stork.
22 Pavilion for Little Children
23 Restaurant of the Freres Provençaux (Paris).
24 Sala di Lettura } of Natale Biffi, of Milan.
25 Restaurant } of Natale Biffi, of Milan.
26 Wine House } of Natale Biffi, of Milan.
27 Iron Hall—Exhibition Hall for Metal Industry.
28 Pavilion of Austrian Mineral Springs.
29 " for Tobacco and Cigars
30 " of the Perlmose Cement Wares, from the Manufactory of J. Newnüller, in Nussdorf.
31 Russian Restaurant.
32 Steirian Dwelling House.
33 Russian Dwelling House.
34 Exhibition of the Austrian Lloyd.
35 Wigwam.
36 Iron Hothouse of R. P. Wagner.
37 Palace of the Viceroy of Egypt.
38 Small Japanese Buildings and Gardens.
39 Cercle Oriental of Dr. Hardt.
40 Turkish Dwelling House.
41 Turkish Bazaar.
42 Turkish Coffee House.
43 Persian Dwelling House.
44 Exhibition of the Imperial Minister of Marine.
45 Light-house of Saulter & Co., Paris.
46 House of the Photographic Association.
47 do. of the Agricultural Society.
48 Sanitary Pavilion.
49 Architectural Hall.
50 Italian Restaurant.
51 Exhibition of the Imperial Gardeners' Society.
52 Pavilion of the Iron Furniture Manufactory of Quittner & Herzog.
53 House of Gardener.

Second Zone.

1 Light-house.
2 Fountain of Sultan Achmed II.
3 Triumphal Arch of the Nienerberger Tile Manufactory.
4 Russian Peasant House.
5 Pump-house.
6 Iron Church.
7 Swedish Restaurant.
8 Norwegian } Fishing Apparatus.
9 Swedish } Fishing Apparatus.
10 Norwegian Garden Kiosk.
11 German Pavilion of Instruction.
12 Germany's " for Industry.
13 German ? Industry Exhibition.
14 Eating House.
15 Pavilion of the Duke of Coburg Gotha.
16 " of Prince Schwarzenberg.
17 " Mauthner.
18 Stable Building of R. Ph. Wagner.
19 Curtis' Obelisk of Cement.
20 Houses of Artificial Stone.
21 Vorderbergen } Mining Industry Exhibition.
22 Innerbergen } Mining Industry Exhibition.
23 Karntner } Mining Industry Exhibition.
24 Pavilion of the Silberegg Brewery.
25 Machine Building Company (Prag).
26 Tar and Asphaltum (J. Bosch).
27 Architectural Ornaments of Zinc (Vinc Wenzel).
28 Steffen's Exhibition of Machinery.
29 Rothschild's Bridge Construction.
30 " Exhibition of Machinery.
31 Slate Exhibition of John Liebig.
32 Wooden Wares (Schubert).
33 Pavilion of the State Railroad.
34 English Restaurant.
35 Pavilion of the Stock Company for Construction of Bridges and Roads.
36 Tyrolean House (Wood-work Exhibition).
37 Additional Exhibition (Contributions to the History of Industry and Invention, and Pavilion for Women's Work).
38 Pavilion.
39 " of the Imp. Danube Steamboat Co.
40 Alsatian Peasant House.
41 Exhibition of the Imp. Agricultural Dep't.
42 Wine Hall of All Nations.
43 Sacher's Restaurant.
44 Pavilion of the Society of Promoting Forest Culture.
45 Pavilion of the Archduke Albrecht.

Fourth Zone.

1 Bakery of Heilfinger.
5 Stand-pipe for Water Service.
6 Iron House of S. C. Hemming & Co.

XI Post, Telegraph and Tax Offices.
XII Guard Houses.
XIII Buildings for Horse Show.
XIV Depot.
W Watch Houses.
A Water Closets
v Covered Passages.

First Zone.

1 American Restaurant.
2 Beer Hall.
3 Beer Hall of the Pilsener Brewery.
4 Hungarian Wine House (Czarda).
5 American Drinking Hall.
6 Pavilion of the "New Free Press."
7 Swiss Confections of Possard, in Zurich.
8 Pavilion of the Musical-Box Manufactory of Heller, in Bern.
9 Beer Hall of the Brewery in Siesing, near Vienna.
10 French Restaurant.
11 Pavilion of the Prince of Monaco.
12 Pavilion of the Finsponk Farm.
13 Swedish School House.
14 Swedish Military Exhibition.
15 Swedish Hunting Pavilion.
16 Gothic Mausoleum, by Wasserberger.

1 Light-house.
2 Fountain of Sultan Achmed II.
3 Triumphal Arch of the Nienerberger Tile Manufactory.
4 Russian Peasant House.
5 Pump-house.
6 Iron Church.
7 Swedish Farm.
8 Pavilion of the Imp. Hung. Forest Comm'rs.
9 Pavilion of the Steirmarck Forest Proprietors.
10 Saxon Peasant House } Siebenbürgen.
11 Szekler " }
12 Austrian School House.
13 Vorarlberger Peasant House.
14 Austrian "
15 Pavilion for Glass Painting.
16 Sclovakisch Peasant House.
17 Croatian "
18 Roumanian "
19 } Gazdeler Peasant Houses (the neighborhood of
20 } Pressburg.)

Third Zone.

1 American Restaurant.
2 Vienna Bakery.
3 English Workman's House.
4 Seed Pavilion.
43 Sacher's Restaurant.
44 Pavilion of the Society of Promoting Forest Culture.
45 Pavilion of the Archduke Albrecht.

Fourth Zone.

1 Bakery of Heilfinger.
2 Coffee House.
3 American Boiler House.
4 English Workman's House.
5 English Boiler House.
6 English Workman's House.
7 French Boiler House.
8 English Gas Works.
9 Gas Company Limited.
10 Belgian Workman's House.
11 Machine Shop.
12 Swiss Boiler House.
13 Belgian "
14 Pavilion of Commerce.
15 German Boiler House.
16 Pavilion for German Tile and Ice Machines.
17 Austrian Boiler House.
18 Pavilion of the Northern Railroad.
19 " " North-western Railroad.
20 Boiler House for the Water Service.
21 Pavilion Ringhofer.

Civil and Mechanical Engineering.

ON THE THEORY OF STEAM GOVERNORS.

By Hugo Bilgram.

It occurs not unfrequently that theoretical views offered for the solution of practical problems are not confirmed by the results of subsequent experiments, simply because the originator of the theory in question omitted to take into consideration facts or conditions which are inseparably connected with the subject, and which seriously affect the practical result. In fact, inaccuracy of this character is almost the only cause that can be given for the disagreement of theoretical and experimental results, and is often committed purposely to simplify the otherwise complicated theoretical deduction. Sometimes, however, practice demonstrates the incorrectness of the suggestion unexpectedly, and the discovery of the error, which may lead to a correction and a more successful solution of the problem, is often difficult. The present article shall ventilate one such mistake, heretofore made in most treatments on the theory of steam governors, showing that a great number of failures in this branch of engineering could have been avoided by a more careful theoretical examination.

It is the function of the governor to regulate the speed of the steam engine so as to maintain its rate as near as possible to a standard, notwithstanding the accidental changes of the load, or of the steam pressure. Its principle is based on the opposite action of two forces upon an arrangement of levers, which are connected with the regulation-valve to accomplish its adjustment. One of these forces is a result of rotary velocity, as centrifugal force, or the resisting force of air or liquids against revolving wings, while the other is independent of rotation, and, in most cases, gravity or the pressure of a spring. The governor being so attached to the engine as to partake of its motion, any change of velocity will cause a change of the first mentioned force and disturb the equilibrium, and the one of the two forces whose momentum is greater after this change will effect a movement of the levers, which is transmitted to the valve, and thus regulates the admission of steam. If the construction of the governor is such that, by the movement effected by either of the two forces, their momenta are changed in a favorable proportion towards the weaker force, and that therefore, after a corresponding change of position,

the latter will have comparatively increased thus much as to check a further adjusting action; then the governor is a static one. It will, for every velocity ranging between certain limits, occupy a corresponding position; it will rise when the speed is increasing, sink while the speed is decreasing, and remain stationary in the corresponding position if the speed is uniform. Most centrifugal governors that are now in use belong to this class. A governor is astatic when for one certain velocity the opposing forces will be in balance at any position of the governor, and hence a movement does not affect the relative proportion of their momenta. It follows that for no other velocity this arrangement will remain in any stable position, but will rise or fall as far as the construction allows it. The parabolic governor is among the number of those which answer to this condition. Some governors are so arranged that any movement alters the proportion of the momenta in favor of the stronger force. Their balance is evidently unstable, wherefore they are unfit for regulating speed, and only men of very superficial knowledge indulge in the doubtful glory of inventing such. It may be remarked here, however, that the centrifugal governor with crossed arms, and a number of others, in their lower position are anastatic, and should, therefore, by suitable stops, be prevented from ranging below a certain limit.

The speed-regulating qualities of the static and the astatic governors are decidedly different, and the following consideration will show which of them is preferable.

Before all things it should be remembered that in all steam engines the steam is admitted and operated periodically. On this account periodical fluctuations of speed at each stroke are inevitable, and they are evidently beyond the correcting influence of the governor. Moreover, as the governor corrects the speed by adjusting the amount of steam admitted at each stroke, its action cannot be anything but periodical. If the regulation is accomplished by throttling the steam, the throttle-valve offers but little resistance to steam that has a small velocity, and effects a successful throttling only while the velocity of the admitted steam is at its highest rate, or near so, that is, at or near the middle of the stroke. If variation of the expansion is the medium of regulation, the instant in which the cut-off takes place is the only time in which the governor exerts its influence upon the admission of steam. At any intermedial time, the governor may assume, at least inside of certain limits, any position, without in the least affecting the production of work. Any movement of the governor will there-

fore realize a change of the performance of work only at one certain stage of the stroke. This fact seems to have been heretofore invariably overlooked, in spite of its decided influence upon the theory of governors.

Because periodical variations are inseparably allied to the speed, and the velocities of the main shaft at different stages of a stroke are different, only those of corresponding stages can be compared for the determination of a change of speed, and the preceding shows that the governor complies with this condition.

Any change of the steam pressure or of the load will cause the speed of an engine to depart from the standard rate. In considering the thus produced abnormal speed, for the purpose of determining means of correction, two points are to be observed: Firstly, the character which shows whether the speed is uniform, increasing or decreasing, and which is the direct result of the relation between the produced work and the load, as the speed will be uniform when the amount of admitted steam is proportionate to the load, and inconformable when a disproportion is prevailing; and, secondly, the deviation of the rate from the standard, which is a secondary product of dynamical disturbances, being dependent on the duration of differences of previous occurrence. The distinction of these two points should be well regarded, for if they are confounded, what, indeed, only too often happens, the theorist is apt to be misled and to arrive at false conclusions. Inconformity of speed can be remedied by a single operation, by simply adjusting the amount of admitted steam until the disturbing difference is corrected. But, although by this process an acceleration or retardation of speed may be checked, yet the change of rate which does take place before the operation is completed will not be reversed, and hence the thus corrected speed, though uniform, will not have the original rate. The static governor is adapted for this regulation, and because the governors which are at present in use almost exclusively belong to this class, their most prominent peculiarities may be enumerated here. According to the principle of their construction, their position, and consequently also that of the regulation-valve, is directly dependent on their velocity. While the speed of the engine changes, the governor is operating, and it ceases its operation after the restoration of conformity of speed. A higher speed corresponds with such a position of the valve that the amount of admitted steam is small, and *vice versa*. There is a highest speed for which the regulation-valve is completely shut, or nearly

so, and a lowest limit of speed at which the valve allows the fullest admittance of steam. The actual speed will vary between these two limits according to the work required. The smaller the comparative difference is between these limits, the more sensitive is the governor. Any static governor can be made more or less sensitive by changing the relation of the motion transmitted from the governor to the valve, so that a like movement of the former causes more or less adjustment of the latter. But when the sensitiveness is increased in this manner, the energy or capacity to overcome frictional resistance is diminished, and hence the increase of sensitiveness is somewhat limited. There is, however, still another limit of quite a different character, arising from the fact that the governor does not as instantaneously influence the production of work as it adjusts the valve, for a greater or smaller part of a stroke has to expire after a change of load before the adjustment becomes effective, and after this the effect of a continued adjustment becomes realized in successive moments following at intervals of the duration of one stroke. The first period, from the change to the first effect, as said, is only a fraction of a stroke, varying in each case, and therefore the first dynamical effect of the governor can be but incomplete, causing the correction of only a part of the difference. The remaining difference should be completely corrected after the lapse of the second period, which has the constant duration of a stroke. The sensitiveness of a governor should therefore be so selected that the change of speed caused by a given dynamical difference during the time of one stroke or of half a revolution of the main shaft, should effect such a degree of adjustment that this difference will just be removed. A less sensitive governor will after the second stroke leave the residue of the partly corrected difference for the third, and again a smaller residue for the fourth stroke, and so on, and will for this reason restore balance between work and load after a much longer period, which, in a strictly mathematical sense, is of infinite duration. Practically, though, the difference left after a number of strokes is so small that the correction can be regarded complete. If, on the contrary, the sensitiveness of a governor is greater, the actuated correction after each full stroke will surpass the required one, necessitating a reverse correction after the next stroke, which, though again being too great, leaves another difference, and therefore the completion of a correction will take a greater number of strokes, if not the surplus of correction after each stroke surpasses the original difference, in which case the restoration

of balance is unattainable, similar as with the astatic governor, that will be considered further below. The above condition for the proper sensitiveness of a governor may be expressed by another formula of a more concise form. The inertia of the fly-wheel and other moving parts of the engine takes up and compensates any difference between work and load, and hence the change of speed per stroke is due to an increase or decrease of the dynamical equivalent of the momentum of inertia equal to the surplus or deficiency of the work generated during this stroke. This difference between the produced and the required work should be revoked by the change of speed taking place in the preceding stroke, and therefore the governor should constitute such a relation between the velocity and the position of the regulation valve, that the change of the dynamical equivalent of the inertia effectuates an equal but inverted change of the work generated during one stroke, or, in other words, that "the sum of the dynamical equivalent of the inertia of the moving parts and the work generated by each charge of steam is constant." Most static governors possess, however, a different degree of sensitiveness of different attitudes, and therefore should be so arranged that the mean sensitiveness of those attitudes in which the governor is used complies with the condition.

According to the above, a static governor, if correctly applied, removes any disturbance of balance in the shortest possible time, but allows a small difference in the rate of speed. Should it be required of the governor to correct not only the inconformity, but also this deviation, a double operation would be necessary. The adjustment which removes the disturbing difference must be extended further than would be necessary to merely restore the balance between work and load, in order to produce a new difference of the reverse character that would cause the rate of the deviated speed to return towards the standard. But before the latter is reached, a reverse action upon the steam-valve must be induced to retract the surplus of adjustment, and restore balance the instant when the rate of the previously disturbed speed again coincides with the standard. The astatic or parabolic governor has generally been recommended, even by authorities, for the accomplishment of this purpose, because by its application "the regulation-valve can assume and remain in any suitable position while the speed is at its normal rate." The question, though, is whether it will, not whether it can do so. The first action of this governor after a disturbance actually performs, as desired, an over-

adjustment, because its tendency to rise or sink is limited only by the extreme positions of the valve, and lasts not only till the speed ceases to increase or decrease, but until a subsequent over-adjustment brought the speed back to the standard. It seems, however, the fact has entirely escaped attention that the second action which ought to reverse the surplus of correction at the instant when normal speed is restored, is not accomplished at all, and that instead of this the over-adjustment is kept up until it occasions another but reverse deviation, the correction of which will be attempted by the governor in the same manner but with a similar result, so that the speed will become alternately accelerated and retarded. The adjusting movement being limited only by the extreme positions of the valve, the latter, by the tendency of the governor, would at any occasion become entirely shut or opened, if it were not for the combined influence of inertia and friction, which prevent too sudden an action. On this account the over-adjustment is less than might be expected, and thus the severity of the fluctuations is somewhat retrenched.

A comparison is decidedly favorable for the static governor, and the allowance of a small difference of the rate for the purpose of gaining a more regular speed preferable to the attempt of preventing this difference of the rate and sacrificing the conformity of speed, without even attaining the end. Experience attests this theory, as parabolic governors are acting very vivaciously, now opening, now shutting the valve, even if the load is comparatively permanent; and they have been abandoned repeatedly, in spite of their recommendation by theorists, while static governors, for the sake of their steady and definitive action, always more or less have been a success.

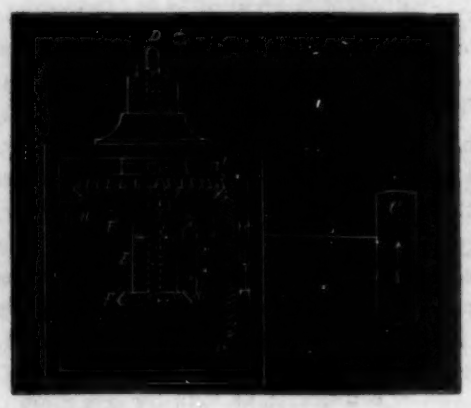
The frictions which oppose the adjusting action prevent an instantaneous action of the governor. In general, it may be said that, on account of friction, the velocity can vary between two limits, which have for every attitude of the governor a definite value, without effecting the adjustment. Only after the velocity transgresses one of these limits does the action commence. It is evident that the governor need not partake in the periodical changes of speed which return with every stroke. If the change of speed that, on account of friction has no adjusting effect, is smaller than or equal to the periodical changes, this resistance prevents only a free play during each stroke, but allows a proper adjustment when the speed in the whole changes, because then the actual change of speed surpasses the change allowed by friction. Only if the friction has a larger mo-

mentum than that defined by the said condition, a delay of the operation is occasioned. Most modern improvements on the arrangement of the suspension-levers of the governor-balls purpose the attainment of a higher energy to overcome frictions in combination with a higher degree of sensitiveness.

The greater part of these frictions proceed from the throttle-valve, or from the arrangement by which the cut-off is varied, and therefore the stuffing-box of the former is generally left so loose as to allow some steam to escape, while cut-off arrangements, which can be adjusted by the feeble power of the governor, are very precarious or complicated. The automatic adjustment of link motion, or some other known variable cut-off valves, is sometimes desirable, but their regulation requires more power than the governor can afford. It would, however, seem curious if the engine builder, at the source of power, would be at a loss for so small an amount of it as is necessary for this adjustment, and therefore the thought lies near to use the governor, not as generator, but merely as a director of the adjusting power. To this end a combination of clutches, which receive their motion from the engine, may be so arranged that the governor only throws them in or out of gear, and they accordingly raise or lower the link or adjust the valve by the power of the engine. But no matter in whatever shape this plan has been tried, it invariably proved to be a failure, for after the engine had been started, the speed gradually run up to a point far above the intended standard, then fell off to a point below the latter, rose again, fell off, and so on, fluctuating in this manner between two limits, alternately rising and falling, and refuge had to be taken to the throttle-valve for the regulation of speed. The cause of this singular phenomenon can easily be accounted for. Although the governor used for operating the clutches may be of static construction, yet the arrangement, as a whole, possesses substantially the peculiarities of the static or parabolic governor, and its powerful action gives the fluctuations of speed due to over-adjustment, as described in the foregoing, a positive character. This will be clear by considering that the respective clutches remain engaged and active as long as the speed is below or above the standard, while it has been shown that the adjusting action ought to last only as long as the speed is increasing or decreasing, or as the balls of a static governor are actually rising or sinking. Being now acquainted with the cause of the failure, the question might be propounded whether the clutches can be so arranged as to make the operation accord with the latter

condition. The answer is in the affirmative, for this end can be obtained by a combination in which the clutches are thrown into gear with the actuating power by the rising or falling movement of the governor balls, and in which, when the balls cease to rise or fall, the said clutches are immediately disengaged from the actuating power through the medium of a screw receiving its motion from the said clutches.

This device, which has recently been patented, can be carried out in various forms, one of which is represented by the accompanying sketch: *A* is a frame on which the governor is placed in the usual way, receiving its motion through the bevel gear, *B B'*, from the pulley, *C*. Rod *D* extends through the hollow shaft, and transmits the rising or falling motion of the balls to the block, *E*, which bears two miter-wheels, *F* and *F'*, ready to gear into the wheel *G*, that is fastened to and revolving with *B*. Block *E* is attached to the rod *D* by means of a screw-thread. Bracket *H* prevents rod *D* from turning. The rotary movement of block *E* is to be utilized for the regulation of the valve-adjusting devices. The application and construction of the receiver and transmitter of this movement is evidently dependent on the nature of the valve, and is therefore not indicated in the sketch, but may be conveniently placed in the space below block *E*. The operation of the arrangement is as follows: When rod *D* descends, clutch *F* will come in gear with wheel *G* and turn block *E* in the direction indicated by an arrow. This movement, however, does not only affect the adjustment of the valve, but also a rising of block *E* in relation to rod *D* on account of the screw-thread on the lower part of the rod, which causes a disengagement of clutch *F* from wheel *G* as soon as the downward movement of rod *D* ceases. A rising of rod *D* will have a similar effect in the opposite direction. But for the action of the screw-thread by which block *E* is attached to rod *D*, the actuating power would remain in gear until rod *D* returns to its original position, and the fatal over-adjustment would again take place.



Chemistry, Physics, Technology, etc.

LIGHTNING AND LIGHTNING-RODS.

By John M. Mott.

Read before the Meteorological Section of the Franklin Institute.

(Continued from page 127.)

A knowledge of the laws of electrical induction, accumulation and conduction, together with a clear understanding of the action and value of points, will enable us, without difficulty, to arrive at correct conclusions in relation to the application of lightning-rods to buildings.

The free electricity with which buildings are charged by induction will, in every instance, accumulate with the greatest intensity upon the ridges and gables, sometimes with greater intensity at one gable than at another. It is therefore absolutely necessary to place a point at each gable, to discharge the accumulated electricity there held by the opposite force contained in the approaching cloud; to place a point at each chimney or ventilator, to offer a line of superior conduction to that offered by ascending smoke, current of heated air or other gaseous matter; to connect all these points together with rods placed along the ridges, and also to connect them with the gas pipes, water pipes, steam pipes, speaking-tubes, or other metallic substances about the building. The more numerous the connections with the earth the better, not only to provide sufficient lines of conduction, by means of which we may so far neutralize the passing cloud as to prevent a disruptive discharge, but also to give the electrical agency an ample line of conduction, so as to prevent intermediate explosion during its transmission. As we depart from this system of applying rods the protection diminishes. Each ground rod should have several branches penetrating the earth to permanent moisture, and where it is difficult to obtain such a termination, they should be imbedded in charcoal. An improper termination of a lightning-rod is to connect it with the gas or water pipes of a city or village beneath the surface of the earth. Theoretically, it is the best possible termination; practically, one of the very worst. The gas and water pipes are not usually very far beneath the surface, but are, at the season of the year when thunder-storms are most prevalent, in comparatively dry soil. I presume the advocates of enormous earth connections, for the

purpose of preventing electrical accumulation, would deem it unsafe to terminate a lightning-rod in such a soil, disconnected from the pipes. I have seen, in many instances, earth connections made with skill and care with both water and gas pipes. I have also seen rods so connected which had been disconnected by the workmen employed by the gas companies or by the city authorities, and either left in a dry soil or wholly disconnected from the earth. If there are gas or water pipes about the building, connect them with the lightning-rod on or in the building. Earth connections by means of such pipes become practicable if this plan of attaching be followed. The rod should also have independent earth connections made in the manner described. A lightning-rod has vastly superior power of conduction to that of the moist earth with which it is in contact, and will for this reason conduct the electricity which accumulates in such stratum, by induction, towards the cloud very rapidly, and in much greater quantities than most men are aware of. The experiment performed by Beccaria, mentioned in the Patent Office Reports on Agriculture for 1859, will be of interest to those who doubt the above conclusion.

If lightning-rods be applied to a building as directed, but terminated in dry soil, in case of a discharge falling upon the rod, damage would not necessarily ensue to the building or its contents. The earth might be thrown up from about the rod, and be scattered in all directions; this result is very often observed, and serves to demonstrate to some minds that lightning-rods are of value, as it furnishes evidence that the rods carried in safety charges which produced wonderful mechanical effects at their lower terminus.

If throwing up a little dirt would encourage the use of rods, I am not sure but it would be of value to the public to advocate a dry soil termination. This policy might, however, lead to disaster, in some cases; therefore we will demand, in every instance, that the rod be terminated in moist earth or imbedded in charcoal.

The conducting power of similar metals, of equal lengths, is proportional to the mass, and not, as frequently erroneously stated, to the surface; and in similar metals of the same sectional area and unequal lengths, it is inversely as their lengths. The form under which metal is placed does not change its conducting power, provided we retain the same weight or sectional area for a given length.

The experiment of Coulomb demonstrating that free electricity resides almost exclusively upon the surface of an *insulated* conductor has proved to be as much a stumbling-block to many electricians as

the one fluid theory of Franklin, and his theory of the action of points upon electrified clouds. Since the molecules in the interior of a conductor discharge with equal readiness on every side, there is no chance for them to become charged; but at the surface of an *insulated* conductor the molecules have conducting molecules upon one side of them, and non-conducting molecules upon the other side, hence their polarization must be followed by the charged state.

If the insulated conductor be connected with the earth, or have a point attached to it, the free electricity will escape. A lightning-rod has one end imbedded in moist earth while the other is terminated in a point.

The conditions are not favorable to have much tension, except at the point, or liability to lateral discharge, as the rod is so situated that discharges from it must necessarily be from one or the other of its extremities. We know that the physical effect of electricity being conducted by metals is to generate heat, that the relative conducting power of metals is determined by noting the degree of heat generated while a given quantity of electricity is passed over wires of uniform size and equal length, made from the different kinds of metals, and that increasing the temperature diminishes the conducting power; hence it is absurd to claim that the conducting power of lightning-rods is proportional to the surface.

Trees near dwellings do not, as many suppose, afford protection; on the contrary, they increase the danger to persons or property in their vicinity and the necessity of using lightning-rods to prevent damage. They offer facilities for a direct discharge, consequently objects near them are in great danger from the return stroke. The fact that trees are injured by lightning is proof that they are poor conductors, while the large numbers of persons and animals annually killed near them by this same element is conclusive evidence that they do not afford the protection claimed.

In newly settled countries the cabins are usually provided with stoves, the pipes of which project through the roof; while these pipes do not in the least attract electricity, they furnish a path of less resistance than that of the surrounding air for its passage, the effect of which has often proved fatal to the occupants.

Barns are very frequently destroyed by lightning. This is owing to several causes: first, efficient lightning-rods have not been erected in a proper manner; second, the combustible material they usually contain and the comparative ease with which it is ignited; third, they

are sometimes filled with hay or grain imperfectly cured or dried, and are also not unfrequently left during the season of thunder-storms surrounded by decomposing vegetable and animal matter. These substances ferment, or "heat," as the farmers term it, and as the gas or vapor rising from the mow or yard into the atmosphere above the barn furnishes a line of less resistance than the surrounding air, it becomes a part of the line of discharge when the cloud approaches sufficiently near so the electrical attraction between the opposite electricities can overcome the resistance.

The annoying and disturbing effects of lightning upon the telegraph are caused by conduction and induction. A charged cloud often covers a space of a hundred square miles or more, extending over lines of telegraph. The point of disruptive discharge may be at a distance of many miles from the wires. When the cloud is over the wires they become charged by induction, and when the discharge ensues, from any point, induction instantly ceases and the wires return, like other objects, to their normal condition.

The effect of this return is often observed upon the instruments when the operator is too far from the point of the discharge to see the flash or to hear the report.

Mr. Crosse, of Broomfield, England, has, by means of wires about one-third of a mile in length, insulated, and supported by means of poles and trees in his park, frequently succeeded in conducting from the atmosphere sufficient electricity to charge and spontaneously discharge a battery of fifty Leyden jars, containing seventy-three feet of coated surface, twenty times in a minute, accompanied by reports as loud as those of a cannon. Telegraph wires conduct free electricity from strata of charged atmosphere in the same manner as the suspended wires of Mr. Crosse, and as the insulators become covered with a thin film of moisture, by the condensation of aqueous vapor, they allow the electricity to pass from the wires to the poles, and as these are imperfect conductors the phenomenon of a disruptive discharge frequently occurs, attended with its well known consequences. If each pole had a wire extending its whole length, attached to it by means of a few small staples, such phenomena would be entirely unknown.

The free electricity from charged strata of air is frequently conducted by the wires into the office in such quantities as are sufficient to melt the fine wire of the instruments.

It is by making a practical application of our knowledge of the

effect of points when attached to charged bodies, namely, increasing the intensity sufficiently to cause a free discharge at any given point, that the instruments and operators are preserved from destruction by lightning. The safeguard is composed of two toothed pieces of metal, disposed so that the teeth are nearly in contact. One of these pieces is attached to the wire and the other is in contact with the earth. If electricity is conducted from the atmosphere by the wire or accumulates upon it or the apparatus, by induction, it is given off by the points in contact with the wire to the piece which is in communication with the earth; disasters are thus avoided.

Oil tanks about the oil distilleries have been exploded; fires have ensued involving great loss, supposed to have originated by being struck by lightning. These tanks are immense air-tight vessels, with the upper portion in the form of a dome.

The lighter portions of these coal oils rise to the top of the dome. These volatile oils are very inflammable, and when mixed with air are as explosive as gunpowder. The atmosphere about the tanks is filled with gas from these oils. The iron tank being a good conductor, well connected with the earth by means of the pipes running to the distilleries, would be easily charged by induction in case a charged cloud should be near it. Its form is such as to secure the maximum amount of accumulated electricity. The tank itself will not offer the least possible attraction for the electricity of the cloud, while the free electricity with which it is charged, by induction, offers great attraction. If a discharge should occur, the inflammable gas about the tank would be ignited before the electricity would reach the tank, and the most disastrous oil explosion and conflagration would ensue, notwithstanding the fact that the tank has sufficient conducting power to conduct with safety every discharge of electricity which may fall upon it from now to eternity.

This tank, which seems, to persons not conversant with electrical laws, to be most safe from injury by lightning, is known, by those who are familiar with such subjects, and who exercise their reasoning faculties, to be exceedingly defective, and in imminent peril during the passage of electrified clouds. A rod of iron or copper, attached to the dome and terminating in a finely plated point, would be a part of the tank, and would perfect its construction. The tank would not now remain in a charged condition; hence there would be no attraction about it. The point would permit a flow of electricity from the earth towards the cloud, and would tend to prevent an explosion.

Oil tanks thus protected would not be injured by lightning. Electricity might pass between other objects in the vicinity, ignite the gas in the air, and in this manner explode the oil in the tank. We thus see while it is quite easy to prevent lightning striking the tank, it is quite difficult to prevent the oil it contains from being exploded from the effects resulting from lightning passing between other bodies, as two clouds.

To escape injury from lightning, protect buildings as herein directed and remain in them during thunder-storms. Keep out of cellars and avoid being near trees during the passage of electrified clouds. In case the gas or water pipes of a building are not connected with the lightning-rods, it is not safe for a person to remain in a position in which his body would become part of the line of least resistance between them. Beds should be removed from the walls. Persons in chairs should be in the centre of the room, and keep their feet off the floor.

Before the application of lightning-rods to vessels, by Sir S. W. Harris, the damages to ships was of frequent occurrence, the loss of life fearful, and the destruction of property immense.

In 1820 S. W. Harris attached copper straps directly to each mast and continued them to the copper sheathing on the ship's bottom. He thus had a continuous system of copper conductors extending from the top of each mast to the water. After a test of twenty-seven years, at the express command of the Queen of England, the honor of knighthood was conferred upon Harris, "in consideration of his very useful inventions."

Since this system of protection has been applied to vessels, in no instance has any damage ensued to a vessel or to a cargo, nor has there been a single human being killed or injured by lightning while on a vessel thus protected. This fact fully demonstrates the theory of non-insulation to be correct, and that lightning can be controlled.

Magazines for storing powder were injured and exploded by lightning in cases where they were without rods, as well as in cases where rods were used which were insulated from the building by being placed at a short distance from it or passed over or through glass, horn or other non-conducting substances. In no instance has a powder magazine been injured by lightning where the rod has been attached directly to the walls. Conductors have been thus applied to powder magazines for about one hundred years.

It must not be taken for granted that if a lightning-rod be erected

without insulation no damage will ensue. Non-insulation is but one of the conditions requisite for safety. All the conditions must be complied with or safety is not attainable. I am of the opinion that the use of glass or other insulators upon rods, together with the theory that rods attract lightning, and protect an area the radius of which is twice the height of the rod above the plane from which it projects, has been the cause of bringing the use of rods into disrepute. These theories are contrary to the teachings of philosophy; are based upon erroneous principles; their application has fully demonstrated their falsity, and led to disastrous results.

The height a rod extends above a building has no influence whatever upon a discharge of electricity further than arises from the fact of its offering a path of less resistance than the surrounding air before the discharge takes place. It is for this reason, solely, that the rod is carried a short distance above the ridge of a building, and is projected above the tops of chimneys, ventilators, &c. It cannot be supposed for a moment that an agency which moves with such terrible velocity and irresistible force as lightning, could be arrested in its onward course and drawn aside by an insignificant piece of metal in the form of a lightning-rod.

If metal does possess this power of arresting lightning, the use of metallic eave-troughs, steam pipes, gas pipes, water pipes, speaking tubes, bell wires, bells, valleys on roofs of buildings, chimney tops, cornices, etc., in and about buildings, should be at once discontinued, as they may attract more electricity than they can carry off, as some ignoramuses have asserted.

The idea that metal attracts electricity is unsupported by any fact, and is absolutely at variance with the whole course of experience. Such an opinion has arisen entirely from assumption and a partial consideration of facts, or from superstition, prejudice or unadulterated ignorance.

Lightning-rods do not attract lightning. They have no influence whatever upon a thunderbolt after it has started, to restore the equilibrium. The height they project above the building is of but little consequence, providing they be kept *low enough* to withstand the storms.

There is no law governing the lateral extent to which a rod affords protection, this being dependent upon the form of the object to which it is applied and the position of the electrified cloud.

If a building or its contents be injured by lightning, it is solely

because its owner has neglected to use well known means to prevent it. Should life be destroyed, in a building, by lightning, the owner or public officers having charge of it should be held responsible by law.

City authorities who will not permit the erection of wooden buildings within the fire limits, lest these structures might endanger the property of others; nor permit a building to stand, whose walls are supposed to be in an unsafe condition, ought not to permit any building to remain in such condition as to endanger the life and property of a neighborhood by lightning.

Summary.

1st. Lightning-rods, as usually erected, do not afford much protection.

2d. Insulators, glasses, at the points of support, are of no use in any case; they destroy the most valuable influence of the rod, and may, under certain circumstances, be the cause of most terrific and destructive return strokes.

3d. The conducting power of lightning-rods is proportional to their solid contents, or sectional area, with similar metals of equal lengths, and not to their surfaces.

4th. A lightning-rod should have the conducting power of a copper rod one-half inch square, and perfect metallic union of all its parts. A rod made exclusively from copper wires, if of sufficient size, constitutes one which is perfect in theory.

5th. Sharp points for the upper termination of rods are necessary. Rods are of but little value without them. Points should be plated, to prevent oxidation. They are also of value when used at the lower terminus of the rod.

6th. It is necessary to place a point at each gable, chimney and ventilator; to connect all together; to connect the rod with metallic roofs, gutters, valleys, steam pipes, gas pipes, water pipes, speaking tubes and other permanent metallic bodies about buildings, and the more numerous the connections with the earth the better.

7th. The rod must be attached directly to the building, the closer the better. It must not be insulated by being passed through or over rings of glass, horn or other non-conducting substances, nor be placed at a distance from the object to be protected.

8th. Ground rods must have two or more branches penetrating the earth to permanent moisture; must extend below the foundation walls

or the bottom of the cellar. In some instances, where it is difficult to reach moist earth, they must be imbedded in charcoal.

9th. Lightning-rods, constructed and erected in accordance with the foregoing principles, will afford full protection in the hour of danger, and their use is strongly urged as a necessary means of safety.

DECAY AND PRESERVATION OF TIMBER.

(By T. J. Cram, Col. U. S. Corps of Engineers, Bvt. Maj. Gen. U. S. A.)

(Continued from page 186.)

V. *The Observed Condition of the Timber after Treatment.*—As might be expected, I have given close attention to this subject, and submit the following conclusions, drawn from my own observations:

1. The albumen in the wood has been coagulated thoroughly.

2. The outer portions of the sticks, the sap wood especially, are thoroughly impregnated.

3. The inner or heart portions of the sticks that contained air, and little or no sap fluids, are not so well filled as the outer parts, the stuffing being abundant on the exterior, and gradually decreasing towards the centre, where there is little or no evidence of it.

4. That substance, whether it be "hydro-carbon" or "resiniferous," coming from the oil and solidifying in the pores of the wood, is apparent, but it does not seem to stop altogether the absorption of water, yet so little water is taken in after treatment that it does not penetrate beyond the carbolic acid of the oil which has entered the wood.

5. Deeper penetration and a larger deposit of the hydro-carbon in the heart wood of the sticks would have been obtained by more oil and more time for the treatment.

6. A given number, say twenty cubic feet, all in one stick, is far more difficult to treat than the same number cut up into small paving blocks, railroad ties or fence posts.

7. In the large straight-grain sticks, the penetration was not so ready nor so abundant as in the cross-grain sticks, showing that the antiseptic enters in directions parallel to the fibres far more easily than transversely to them. It is for this reason that the shorter the stick (like paving blocks, ties and fence posts) the more readily it becomes saturated.

8. In our operations the strength of the timber was not impaired; it was found of greater rigidity after the treatment, and as much lighter

as was equal to the difference of weight of fluids expelled from the green water-logged timber and the substance taken in; it was, however, rendered a little more brittle; but, though the "co-efficients" of elasticity and rupture should be slightly diminished by the process, still the timber would be amply strong, laid in piers, docks and railroads.

9. Could we have framed the timber, by cutting all the notches and dovetails before treatment, it would have been better for the work.

10. It is clearly shown in my observations that it will not do to trust implicitly to samples of wood of small dimensions which have been submitted to the process, for facts to govern us in drawing inferences to apply to large sticks of timber, either for the quantity of the antiseptic imbibed, the amount of the hydro-carbon left in the pores, or for the strength of the wood after treatment, or its weight.

11. It is not yet being two years since commencing the treatment, and immediately putting the timber into the construction, it is impossible to give results that may be observed five years hence, at the expiration of the first period of seven years. The treated sticks are marked in the work with a double cross (× ×), and the untreated with a single (×), and they lie side by side similarly exposed to all circumstances causing decay. At the end of the first period a comparison carefully made will give us the data upon which to judge whether we shall realize anything of what we hope to gain by this great experiment.

12. The inflammability of the wood for the first season after treatment is somewhat increased, though not so much as to cause objection to it for pier constructions. In a hot summer day immediately after treatment, the timber having been turned from its bright clean color to a dirty, sooty brown or black, by the process, was disagreeable to the men to handle, but all complaints arising on this score were due more to imagination or carelessness than to any well founded cause.

13. The whole atmosphere at the work was impregnated with the odor of the tank and scattered piles of treated timber, which was undoubtedly a strong promoter of health to the workmen. I have never known a public work in a marshy influence employing from two hundred to three hundred men as free from malarious diseases to the men or from sickness of any kind. I attribute this remarkable freedom from ill health to the antiseptic influence of the impregnated atmosphere.

VI. *Quantity of Timber Treated. Time of Treatment. Oil Consumed. Cost of Treatment.*—The whole amount treated was 186,580 cubic feet, in sticks of the sizes already given in Chapter III. I intended to have more treated, but the apparatus could not be made ready before the constructing contractor had to commence putting in his work.

The time consumed for each batch was twelve hours, *i. e.*, from when it entered to when it left the tank; the amount of timber in the tank was on an average of 1,100 cubic feet.

When the timber was on hand in good supply, and the apparatus in good working order, and the men diligent, the amount treated in a month of twenty-six working days was 27,738 cubic feet. This is a fair measure of what can be done with large timber that is green and water soaked, in a single tank of the dimensions of the one used.

The quantity of oil consumed for the saturation of the timber in any given case depends on the kind of wood, the thickness and lengths of the sticks and the time taken for keeping the wood under the treatment. The heating of the oil is only continued until all the water and gases are expelled or cease to come over from the pores of the wood.

In our treatment of the *large wet and green, white and red pine sticks*, the oil consumed was one-half ($\frac{1}{2}$) gallon to the cubic foot of timber, on an average, throughout the whole. It cost, delivered at the works, 15 2-10ths cents per gallon. In working the apparatus, one foreman, at $150 per month, and four hands, at $75 each per month, required, making the hire of men to amount to $450 per month. Allow for wear and tear of machinery $75 per month, and for fuel $33.75 per month.

The expenses per month, therefore, amounted for oil, labor, wear and tear, and fuel, to $2,666.84. This divided by 27,738, the number of cubic feet treated, would bring the cost of treatment to very nearly 9·61 cents per cubic foot of the timber, without including the cost of the apparatus.

The apparatus complete, including shed, costs not less than $9000. I have no idea of the royalty paid the patentee. I find that on the whole job the contractor, after deducting the cost of the apparatus, could not have realized more than $1056.66 to cover the royalty, the interest on his outlay, his personal expenses for two seasons, besides

what the machinery would be worth, after completing the contract for 186,580 cubic feet.

The contractor for treating the timber, from isolated locality, and being subordinate to the constructing contractor for the supply of timber, was put to expense and loss of time, which would have been saved under more favorable circumstances.

The estimate I have given furnishes the proper criteria to enable one to judge, if he has a given quantity of timber to treat, whether it would be best to purchase the right, construct the apparatus and do the work for himself, or to hire the authorized agent of the patentee to treat the timber by the cubic foot. The cost of treatment may be considerably diminished from the foregoing estimate by attending to what follows in the next chapter.

VII. *Improvements Suggested in the Apparatus.*—Having seen the working in the operations for two seasons, I am prepared to recommend:

1st. That the swinging crane, which was worked by hand for loading and unloading the cars, should be so arranged that the lifting may be done by the steam engine, thus saving the labor of two men, and keeping the engine employed, instead of resting idle half the time.

2d. The timber tank should be covered with a wooden shell, leaving space, however, between it and the tank to allow the water jets to play, in the "cooling off," and thus prevent a loss of heat by radiation, and effect a saving of both time and fuel.

3d. Instead of a full circle, give the timber tank a cross section, like Fig. 6, rounding, however, the lower corners; then less oil would be required to cover the batch, and the timbers could be separated by horizontal and vertical spaces (as in Fig. 6) by thin strips of wood or iron, leaving channels for freedom of circulation of oil all around each stick while heating; and by this shape, too, a large coil of steam pipe could be introduced, and less time occupied in raising the temperature of the oil to the required degree, which, however, should not exceed 290° or 300° F., for much above 300° F. would impair the wood fibre and distil over the oil.

4th. When there is a large quantity of timber to treat, there should be two timber tanks instead of one only, so arranged that while the oil in one is heating the other would receive its batch, and the hot oil from the first flowed into the second as soon as the time comes to cool off in the first.

5th. Put a valve into escape pipe δ, to retard at pleasure the escape of steam.

6th. Use a ten-horse-power steam engine with a boiler commonly used with a twenty-horse-power steam engine.

With an apparatus thus improved, one engineer, two skilled laborers all the time, and occasionally a common laborer, could conduct the whole process.

I would also improve the *name* of the treatment. Instead of calling it, what it is not, "creosoting wood," I would designate it by what it really is, viz.:

Carbolic acidizing wood. The chemical tests applied showed that no creosote entered the pores of the wood in the process. If any creosote is found after the treatment, it must have pre-existed therein. Empty the pores and stuff the cells with creosote, and I venture to say the wood will sooner perish.

VIII. *Estimate of the Saving to the Government by the Carbolic Acidizing of the Timber at the St. Clair Flats Improvement.*—I will make the formulæ general, and apply them to this improvement as an example for showing not only the saving on this, but on any other work:

Let t be the first cost in cents per cubic foot of the timber delivered at the location of the apparatus; f the cost in cents per cubic foot of framing and putting the timber into the work, including, on renewing, incidentals thereto; c the cost in cents per cubic foot of the treatment.

We see in Table C, Chapter II, that timber similarly exposed and of like kind, and even of inferior quality, has lasted in Europe, after treatment by Bethel's process, 19, 20, 24, 26, 32 years, and then found as sound as ever; and at the present time all the information I can obtain proves those timbers perfectly sound. There is no knowing yet how much longer they will last. The prevailing impression is with some engineers who have examined them, that they will last until literally worn out. I have a right, therefore, to suppose or assume that the timber treated by the Seely process for the St. Clair Flats Improvement will endure for twenty-eight years before renewals will be required. If time to come proves the assumption to be wrong, the mistake on this point must then be attributed to the circumstance of a decided difference yet to be found between the durations of treated seasoned and treated green timber. Be this as it may,

twenty-eight years is the epoch of duration for the treated, and seven years for the untreated, before this will require renewal. Again, the government pays on its borrowed money an interest equivalent to six per cent. per annum, and in making an estimate involving borrowed capital, the interest thereon must be compounded in order to arrive at the true state of the case. Upon the basis now stated we have the following formula:

$$\left.\begin{aligned} \text{Cost in cents per cubic foot untreated, for 28 years} &= 12{\cdot}276 \times (t+f) \\ \text{Cost in cents per cubic foot treated, for 28 years} &= 5{\cdot}112 \times (t+f+c) \\ \text{Saving cents per cubic foot by treatment, for 28 years} &= 7{\cdot}164\,(t+f) - 5{\cdot}112 \times c \end{aligned}\right\} (3)$$

In the St. Clair Flats Improvements $t = 21$ 3-10ths cents; $f =$ 9 7-10ths cents; $c = 15$ cents. Substituting these in the last formulæ (3), we find:

Saving per cubic foot by treatment, for twenty-eight years = 145 4-10ths cents; or, the annual average saving in this epoch, 5 2-10ths cents on every treated cubic foot in the work, which contains 186,258 cubic feet treated; or, an annual saving of $9685.42 on the work in consequence of the treatment.

We shall never hereafter obtain this quality of timber, nor get it framed and put in the work for less than 21 3-10ths cents for t, and 9 7-10ths for f. But I am confident, with the improvements I have suggested in Chapter VII for the apparatus, the cost could be made less than fifteen cents for c, unless the oil should advance very much in price above 15 2-10ths cents per gallon.

For determining the limit of c, above which it would not be profitable to treat the timber, we have the expression $7{\cdot}164 \times (t+f) - 5{\cdot}112 \times c = 0$; from which we find $c = 1{\cdot}4014 \times (t+f)$; *i. e*, when the cost per cubic foot for the treatment is *one and four-tenths* the cost of the timber and the labor of framing and putting it into the work, there would be nothing gained by the treatment. This simple rule applied to St. Clair Flats Improvement, gives the limit of c equal to 43·4 cents.

IX. *Question of Applying the Seely Process for Preserving Timber to all hereafter to be used in Repairs, Preservation and Construction of Piers, and Breakwaters on the Lakes.*—If these works are to be kept up in good serviceable shape by appropriations from the national

treasury, as ought to be, it will be in place here to briefly present the measure of the economy of this question; also the practical method of effecting this object.

There would be no necessity of treating any of the timber except that above water, and which I call the "superstructure."

In all the harbor piers, breakwaters, etc., upon the lakes, there are probably fifteen miles or more in extent of superstructure. The width will average at least eighteen feet, and height five feet, or five timbers above water. Experience has shown that they should all be planked over. To every running foot pierwise the superstructure will contain at least twenty cubic feet of timber on an average of all the works. In the fifteen miles, therefore, there are 1,584,000 cubic feet exposed to decay and requiring renewal. In periods of seven years to each work, its proportional part of this should be renewed. This estimate does not include the new works to be commenced hereafter, but the formulæ may be applied to them as readily as to existing work.

In every renewal of timber in the superstructure there is attendant or incidental labor of $2 per cord, for removing and replacing the stone filling without waste, in order to put in the new timber. This incidental item I find averages six and a quarter cents to every cubic foot of timber in the superstructure. Again, the cost of the iron drift bolts and spikes has to be again incurred at every renewal. I have made several attempts to save the old bolts and spikes, but the expense of pulling, straightening, etc., has proved more than they are worth. In the superstructure there is just about one pound of bolts and spikes to the cubic foot of timber, which at present prices costs not less than 4 1-6th cents, which is another incidental expense at every renewal. Since we have these for every cubic foot of the timber, we may add them to the cost of framing and putting in the timber, which will never be less than ten cents per cubic foot on an average. Putting the three foregoing items together, we shall have $f =$ (10 + 6¼ + 4 6-10) 20·85 cents.

The untreated square timber itself will cost, provided the plans be made as they should be, to require sticks not to exceed twenty-four feet in length, twenty-one and a half cents on an average delivered at the works, or first delivered at a properly selected place, which I shall name, for the location of an apparatus for treating all the timber before sending it off to the several harbor piers, for the renewals. Hence, we may put $t = 21\frac{1}{2}$ cents.

The treatment of the timber, including royalty for the patent, would probably cost eleven cents per cubic foot after the apparatus is constructed.

The total cost of the apparatus, improved as I have suggested, including preparation of the "Timber Bay," to receive the green timber before treatment, need not exceed $12,000, which, divided by the whole number of cubic feet to be treated, would be very nearly 76-100th cent per cubic foot. This item is chargeable to the account for treatment.

Again, the cost for freighting the treated timber from the site of the apparatus to the several harbors where the timber would be used would average $4 per thousand, board measure, or 4 8-10ths cents per cubic foot. This is another item chargeable to the account of the treatment.

Bringing the last three items together, we shall have

$$c = (11 + 0{\cdot}76 + 4{\cdot}8) = 16{\cdot}56 \text{ cents.}$$

By substituting the foregoing values for t, f, c, in the formulæ (3), we shall find the saving by the treatment, for an epoch of twenty-eight years, to be 218·74, or 7·81 cents annually per cubic foot, which, applied to the whole amount, would bring the whole saving to amount annually to $123,710.40, in consequence of the carbolic acidizing by the Seely process.

NOTE.—If, on a careful summing up from the records in the Chief Engineer's office at Washington, there should be found more or less than fifteen miles of such piers and breakwater constructions, this estimated amount of saving can be modified proportionally.

The best site the government could select for establishing the apparatus for treating the timber is at Fort Wayne, near Detroit, where there is an excellent harbor, a good United States engineer dock already; also, extensive river front for making the "Timber Bay," and plenty of ground, all belonging to the United States.

If two such places should be deemed advisable, probably Green Bay, Wis., at or near the site of old Fort Howard, would be the most advantageous place on Lake Michigan.

All of which is respectfully submitted,

T. J. CRAM,

Col. ret'd Corps Eng'rs, Bvt. Maj.-Gen. U. S. A.

To Brig.-Gen. A. A. HUMPHREYS,

Chief of Engineers, U. S. A.

Detroit, Dec. 15, 1870.

NEW YORK, *Dec.* 10, 1870.

Brig.-Gen. A. A. HUMPHREYS,
Chief of Engineers, U. S. A., Washington, D. C.

GENERAL,—After careful inquiry concerning the various methods of preserving timber from decay, and from the attacks of land and marine insects, now practiced, I am convinced that the *Bethel* process, patented in England in the year 1838, and the two American modifications of it known respectively as the *Seely* and the *Robbins* process are both cheaper and more effectual than any other preservative methods now in use.

They consist in impregnating the timber, to a greater or less degree, with carbolic acid contained in the creosote of coal tar.

By the *Bethel* process, the timber is placed in an air-tight cylinder of boiler iron, which is then exhausted of air to the point indicated by 20° on the Bourdon vacuum gauge. At this point the creosote is admitted into the cylinder at a temperature of about 120° Fahr., at once filling it to within an inch or two of the top. A pressure of about 150 pounds per square inch is then applied, and maintained for from five to eight hours, depending on the size of the pieces of timber under treatment. The creosote is then drawn off and the timber removed.

The *Seely* process, in brief, consists (1) in subjecting the wood to a temperature above the boiling point of water, and below 300° Fahr., while immersed in a bath of creosote oil for a sufficient length of time to expel the moisture. When the water is thus expelled the pores contain only steam, and (2) the hot oil is quickly replaced by a bath of cold oil, by means of which change the steam in the pores of the wood is condensed, and a vacuum formed, into which the oil is forced by atmospheric pressure and capillary attraction.

Six to twelve pounds of creosote oil to the cubic foot of wood is expended in this process; the amount depending upon the use to which the wood is to be put. For piles or other timber exposed to the depredation of worms, twelve pounds is used.

For gun platforms it is thought that nine or ten pounds will be sufficient. An impregnation of ten pounds to the cubic foot costs 25 cents. For piles the usual charge is 30 cents per cubic foot.

At 25 cents per cubic foot, the cost of curing the 15-inch gun platforms, of the design recently sent to the Chief of Engineers, would be about $108 for each platform. The quantity of timber in these platforms may, perhaps, be somewhat reduced.

The Robbins process consists in treating wood with coal tar of

other oleaginous substances in the form of vapor. The wood is placed in an air-tight iron chamber, connected with which is a still or retort over a furnace.

When heat is applied the vapor of naphtha is generated at 250° to 300° Fahr., the creosote oil vapor at 360° to 400°, and the heavier tar oils at 500° to 600°. The wood is thus exposed for from six to twelve hours, when the curing is considered complete.

By the Robbins process, it is impossible to charge the wood with more than a small fraction of the amount of carbolic acid, and the other component parts of coal tar, habitually expended in the Seely process. The Seely process appears to be, and is claimed to be, an improvement on the parent process of Bethel, to which we are obliged to refer for all evidences of the durability of creosoted wood.

It will cost $8.00 per thousand feet, board measure, to get timber treated by the Robbins process, or about $42 for each 15-inch gun platform.

I am not prepared to recommend this process, it being by no means certain that evidences of the value of the Bethel process apply to the Robbins modification of it, but they do apply, in my judgment, to the Seely process.

The parent process of Bethel is not practised in the United States.

My reply to that portion of the Department letter to which this communication refers is, therefore, that the most approved wood preservative process now practiced in the United States is known as *Seely's*, and that by it the front pintle wooden platforms for 15-inch guns, after the design recently forwarded by me to the Chief of Engineers, may be treated at a cost of about $108 each, and that the quantity of timber in those platforms may, perhaps, be safely reduced to such extent that the cost of creosoting will not exceed $100 per platform. A platform for 120° traverse contains 375 cubic feet, and one for 140°, 427 cubic feet.

This takes no account of foundations, which may be of either stone, concrete or timber.

I believe that a wooden platform, *thoroughly creosoted*, would last twenty to thirty years, and be better than a stone platform during that entire period. I think it is very important, and indeed essential, that the wood should be completely saturated with creosote at the moment when the temperature of both is above the boiling point of water, in order to secure the best results.

Very respectfully, your obedient servant,

Q. A. GILLMORE, *Major of Engineers, Bvt. Major-General.*

ON THE MOLECULAR CHANGES PRODUCED IN IRON BY VARIATIONS OF TEMPERATURE.*

By Prof. R. H. Thurston.

1. To determine with accuracy what are the molecular changes which are produced in iron by variations of temperature, and of other physical conditions, it should be first ascertained, by experiment and observation, what are the normal relations of the molecules, and, afterward, by similar means, in what way and to what extent, those relations may be naturally or artificially altered.

So much having been done, the investigation of the changes in the mechanical properties of iron, which result from these molecular changes, is a secondary research, and should naturally follow the preceding, as its sequel.

The almost insuperable difficulties which are encountered in attempting to deal with particles of seemingly infinitesimal dimensions, and with intermolecular spaces of immeasurably minute extent, have, as yet, prevented a satisfactory prosecution of the first part of the investigation by even the ablest physicist, and the second division of the subject still remains as a problem only partially solved, notwithstanding the fact that a considerable amount of experiment and discussion has thrown light upon it.

2. The following may be considered as a statement of the most generally accepted views of the molecular constitution of matter—views which are usually considered to most fully accord with observed phenomena.

(1.) All matter consists of indefinitely small parts, having dimensions and forms which are unchangeable by finite power, and which are endued with the properties of impenetrability and inertia.

(2.) These "atoms" are separated by spaces which are absolutely very small, but which are immensely great in comparison with the atoms themselves.

(3.) Several atoms, when united by chemical force, form a molecule, and aggregations of molecules, with intermolecular spaces, make up the masses of all matter.

(4.) Forces, both of attraction and repulsion, exist between atoms and molecules. These forces vary, in intensity, with changes of distance between molecules. The resultant of these sets of forces is sometimes attractive and sometimes repulsive, changing at times, and under definite conditions, from the one direction to the other. There

* From "The Iron Age."

may thus be exhibited several alternations of attraction and repulsion within a very minute range.

(5). At sensible and measurable distances the attractive force varies inversely as the square of the distance between the centres of attraction, and is termed gravitation.

(6). Gases manifest repulsion only in a degree which, in "permanent," or perfect, gases, varies inversely as the volume of the mass.

Liquids exhibit a perfect equilibrium of attractive and repulsive forces, but offer immense resistance to the disturbance of that equilibrium, by effort to reduce their volume appreciably, and less, although still considerable, resistance to its disturbance by increase of volume.

Liquids, however, offer exceedingly slight, and sometimes immeasurably slight, resistance to change of relative position of their particles, which, therefore, move more or less freely among each other, according to the greater or less viscosity of the liquid. They thus offer little or no resistance to change of form.

Solids are composed of aggregated molecules existing in the same condition of equilibrium as is seen in liquids, and offering similar resistance to change of volume, but they differ from liquids in exhibiting resistance to change of form, which resistance can usually only be overcome by actual destruction of cohesive force. This peculiar condition is the result of that form of force which has been termed "polarity."

(7). These three forms of matter are not distinctly separated from each other, but the same substance may pass, by gradual change, from one to another of the several classes, and may, in its ordinary state, exhibit such physical characteristics as to make it difficult to determine to which of two classes it is to be assigned.

In addition to the above it may be added:

(8). Solid bodies offer a resistance to change of form, which, within narrow limits, is proportioned to the magnitude of that distortion.

Beyond these limits the force producing change of form soon separates the atoms completely, by overcoming gradually the inter-atomic forces, and rupture takes place.

3. The last principle was discovered two centuries ago by that wonderfully acute philosopher, Robert Hooke, who published in 1678 his now well-known law, "*ut tensio sic vis.*"

The first seven of the preceding principles embody the general theory of Roger Joseph Boscovitch, who first published it in an important treatise printed in Vienna in 1759.

Both of these early philosophers based their theories upon such unsatisfactory experiments as they were able to observe before scientific methods had begun to exhibit the exactness and the delicacy now characterizing them.

It seems equally remarkable that their deductions should accord so perfectly with later determinations, and that so little progress should have been made since, in researches upon inter-molecular relations.

That portion of the theory of Boscovitch which supposes several alternations of attractive and repellant resultant forces, has received some apparent confirmation by experiment, but it is by no means proven. It would seem more probable that the attraction of cohesion, and the repulsive force of heat energy, are the two simple intermolecular forces which determine intermolecular distances.

Rankine's theory of molecular vortices affords a hint as to the possible action of heat here referred to.

4. It would seem very possible that phenomena apparently conflicting with this latter belief, will find explanation in molecular changes of position, rather than in the interaction of forces differing in nature, from those familiar to us.

In all familiar examples of solids the force of repulsion increases more rapidly than that of attraction, as the molecules are forced to approach each other, and the reverse is observed as they separate. The molecules occupy, when undisturbed by external forces, positions of equilibrium which have been attained by passing over a range through which, at a constant temperature, attractive force has predominated, and the alternations referred to above, can, if observed at all, only be seen after compressing the mass and forcing the particles past this first position of equilibrium.

The other principles stated, if not absolutely proven by experiment, are at least rendered extremely probable, and are uncontradicted by any recorded phenomena.

Hooke's law has been proven sufficiently exact by numerous experimenters upon the tensile and compressible resistances of materials, and by Chevandier and Wertheim, and later, more fully, but not with more precision, by the writer, in a series of experiments upon torsional resistances, in which the apparatus was made self-registering.*

* Journal Franklin Institute, April, 1873.

5. We remain at present in almost perfect ignorance of the true nature and exact relations of the forces which are concerned in determining these physical conditions of matter.

So much as is known is, apparently, in conflict with every hypothesis yet proposed, in some essential point, yet we cannot resist the conviction that these forces are simple modifications of those most familiar to us; the attractive force being that of cohesion, and the repellant force being that of heat motion, while a third force, or third component of the one force, is that known as "polarity."

It would seem, from the experiments of Coulomb, Professor Henry, Plateau and others, that the elasticity and resistance of solids are due, principally, to the action of molecular forces during changes of molecular grouping, rather than to changes of distances between particles. The latter has an exceedingly slight range, but, as shown by those experiments of Wertheim, which indicate an alteration of volume by tensile stress, an actual, though slight, change of atomic distances does probably take place.

It cannot be asserted that these experiments are absolutely conclusive on this point.

6. The experiments of Professor Baden Powell upon the effect of heat in altering the breadth and diameter of Newton's rings,* are strongly confirmatory of the opinion, already expressed, that the repulsive force of the intermolecular spaces is that of heat motion.

7. The experiments of Dr. Andrews upon the "critical state" of substances passing from the liquid to the gaseous condition, and *vice versa*, are considered, by him, to indicate that those states are "but widely separated forms of the same conditions of matter," and that the one may be made to pass into the other without abrupt change.†

M. Cagniard de la Tour made the earliest experiments in this field in 1822, and was closely followed by Faraday.

Dr. Andrews' more recent researches are probably the most complete and the most fruitful. His investigations of the phenomena accompanying the changes of carbonic acid, as to temperature and pressure, and, particularly, while passing through that phase of transition known as the "critical state," have thrown some light upon molecular relations.

The "critical state" is that condition of matter in which it exists when just passing from the liquid to the gaseous state, or the reverse, by a regular, as distinguished from the more familiar, irregular pro-

† Phil. Trans., 1834. † Phil. Trans., 1869.

cess. It constitutes the "debatable ground" between these two states of matter, whence it is impossible to determine in which condition it should properly be considered.

It is found that, when just approaching this point, liquids are even more compressible than in the antecedent gaseous condition.

Water passes through the critical state at a temperature estimated at about 770° Fahr. by M. Cagniard de la Tour, and at a pressure too high to be accurately measurable.

At this high temperature and pressure it dissolved the glass tubes in which it was attempted to confine it.

8. Dr. Andrews found that carbonic acid exhibited this gradual and regular change from the gaseous to the liquid condition at a much lower temperature.

The experiments of M. Tresca on the "flow of solids"* are exceedingly interesting and valuable in this connection, as lending confirmation to the views expressed by Dr. Andrews.

The phenomena of the critical state are considered by high authorities as strongly confirmatory of that portion of the Boscovitch theory which most requires confirmation.

9. After having passed from the gaseous to the liquid state, matter is found exceedingly difficult to reduce in volume. A pressure of one atmosphere produces, in the case of water, a decrease of volume of but *forty-six one millionths*.†

10. In liquids, attractive force makes itself observable, although the extreme mobility of their particles prevents the ready or accurate measurement of its value.

Professor Henry, who made the first attempt to estimate it, considers that the cohesive force of water is several hundred pounds per square inch. This considerable force resists change of distance between molecules, but does not perceptibly influence change of form, and we have, therefore, the curious fact to observe, here, of the coexistence of high cohesive force with almost perfect mobility of particles; the latter condition rendering the resistance to change of form very difficult of detection and measurement.

11. In the process of transition from the liquid to the solid state, in addition to the generally continued diminution of volume, molecular approximation, and the assumption of new positions of equilib-

* London *Engineering*, 1866–67.

† John Canton, Trans. Royal Soc., 1762.

rium by the particles, in consequence of the abstraction of heat, another, as yet unexplained, action occurs, which may be called, for want of a better term, *molecular polarization.*

This new force comes into play at a point which is definitely fixed, for each substance, on the scale of temperature, and although the resistance to forces tending to produce changes of intermolecular distances may be but little increased, resistance to change of form makes itself observable, generally suddenly, and solidification is produced by the fixation of molecules in definite relative positions.

The characteristic which distinguishes the solid from the liquid state is the effect, apparently, of this force of "*polarity*," simply.

Dr. Henry remarks "It is in accordance with the phenomena of cohesion to suppose that when a solid is liquefied by increase of temperature, instead of the attraction of the liquids being neutralized by the heat, that the effect of this agent is merely to neutralize the polarity of the molecules, so as to give them perfect freedom of motion around every imaginable axis." This author was probably the earliest to detect, and to state thus precisely, the part played by this force of polarity in molecular phenomena.

12. The cohesive force which makes its appearance when a gas becomes liquified is probably considerably increased in all cases when solidification occurs; but the mobility characteristic of the liquid state is so perfect that it is difficult to make the comparison, and we, consequently, have scarcely any reliable data from which to estimate the value of cohesion in fluids. The most valuable are probably those of Prof. Henry,* already referred to, from which he estimated the cohesion of water to be nearly that of ice.

13. In the cases of some, and, probably, of many solids, the relation of these intermolecular forces becomes such that, if the force of polarity is overcome, and the molecules forced from the relative positions which they originally assumed, without, at the same time, changing their relative distances to such an extent as to destroy their tenacity, they may slide into new positions in which they will tend, under the action of this polarity, to remain permanently as before. The action here referred to is illustrated by some of Coulomb's experiments on torsion, by those of the writer on the same point, by M. Tresca's experiments on the flow of solids, and by the common methods of "squirting" lead pipe and of "spinning" brass.

* Proceedings Am. Phil. Soc., 1844.

In the experiments of Coulomb, a wire which had been twisted so far as to have taken a permanent set, was found to have its elasticity still unimpaired, and could be twisted as far, without taking a new set, as it could originally before taking the first. In some examples, several successive positions of set, with equal elastic limits, were found. Even a thread of clay, soft and plastic as it is, exhibits this peculiar action. The experiments of the writer on iron and steel $\frac{5}{8}$ of an inch in diameter give precisely similar results.

These experiments are usually quoted in support of the Boscovitch theory of alternation of attraction and repulsion, but it may certainly be questioned whether the view just presented is not by far the more probable one—the successive sets being produced by successive renewals of the action of polarity, as the molecules were forced to move among each other without such increase of intermolecular distances as to destroy their cohesion.

14. In cases of true crystallization we have no means of determining whether the formation of the crystal, in its invariable and symmetrical form, is due to Prof. Henry's polarizing force, or to still another distinct force, or component of the one intermolecular action.

Since, however, it would be generally supposed that one force may produce both phases of polarization, the universally recognized "principle of least action" in nature suggests the belief that there is but one.

The phenomena of magnetism, and of diamagnetism, are undoubtedly exhibitions of molecular action, under these intermolecular forces, but it remains to be determined whether they are, also, produced by the force under consideration.

The experiments of MM. Chedeville and Treve, at Brest, and of other experimenters, indicate, at least, some relationship between, if not the identity of, these forces.

15. It is sufficiently evident that, granting the relation of these several forces to be such as is indicated by what has preceded, the attractive, repulsive and polarizing forces of matter may have any relation of intensity, and, consequently, that substances may exist in very various conditions.

We may have a mass of matter, in which repulsion, of any degree of intensity, may be recognized only, as with the gases; attraction and repulsion may equilibrate each other, uniting to produce a mass resisting change of molecular distance, with any degree of force, and yet, in the absence of polarity, offering little or no resistance to change

of form, as is the case with the mobide liquids. The addition of the polarizing force confers viscosity upon liquids, and this viscosity has every value until, as it becomes great, in proportion to the intensity of the other forces, we find the mass rigid, and, if cohesion is, at the same time, considerable, the body is hard. A body like the diamond would have great cohesion, and, relatively, still greater polarity; iron exhibits great cohesion and considerable polarity, at ordinary temperatures, polarity vanishing faster than cohesion, probably, when the metal is heated.

16. There are some remarkable, and still mysterious, molecular phenomena for which we have neither the space nor the data necessary for their discussion.

The most striking is what may be termed molecular friction. This peculiar phenomenon has been frequently noted, but does not appear to have attracted the attention or to have provoked the careful research that its possible importance should have prompted.

If a bar of steel is magnetized and demagnetized, it is noticed that it most readily accepts afterward the polarity first conferred upon it. What is known as "residual magnetism" is another method, probably, of manifestation of the same action. It is well settled that magnetic phenomena are phenomena of, or invariably accompanied by, molecular movement, and there appears, in these cases, to be exhibited a kind of interatomic friction which, producing a "set," prevents the return of the particles to their original positions, and allows the force of polarity to be most readily overcome in a definite direction.

The "fatigue" of metals, which has been so fully and elegantly investigated by Wohler,* may be an exhibition of the effect of similar causes. It may, however, be simply due to unequal tension, and the consequent gradual rupture, successively, of overstrained portions of metal, the work being thus thrown upon smaller and smaller sections of sound metal, until the whole becomes finally disrupted.

The determination of the effects of chemical changes upon molecular tensions presents a wide and, as yet, almost absolutely unknown field of research.

For one of the most complete and consistent theories of molecular physics which has been proposed, we are indebted to Prof. W. A. Norton.†

* *Uber die Festigkeitsversuche mit Eisen und Stahl:* A. Wohler, Berlin, 1870.

†American Journal Science and Arts, 1872.

17. It will require much additional experimental investigation, and far more carefully planned and systematic research than has been yet given to the subject, to furnish the basis for a perfectly satisfactory theory of the nature and modes of action of corpuscular forces.

If we may draw any conclusions from what is known already, we should probably infer that, when in the gaseous condition, the molecules of matter tend continually to separate, under the action of a repellant molecular force, which has greater magnitude as the gas is compressed.

As this compression goes on, either by the application of mechanical force, or by the abstraction of heat, a point is finally reached at which an equilibrium occurs between the forces tending to produce a reduction of volume and those tending to expand the mass.

Any effort which may be made to destroy this equilibrium, and to increase the intermolecular distances, and, by the same action, to enlarge the volume, may be found, as in the case of water, to be resisted with some force, while an effort to produce a change of distance, by forcing the particles from their positions of equilibrium in the other direction, reducing the volume, may meet very great resistance. And while resistance to change of distance is observed, it may happen that the resistance to change of position, among the molecules in a group may be, and often is, quite unobservable.

18. Abstracting heat still further, solidification finally occurs.

As, throughout the process of contraction, up to this point, the attractive force has gradually increased, in its power of resisting disturbance of equilibrium and change of molecular distances, it would be anticipated that the solid would exhibit greater cohesion than the liquid. There is but little evidence bearing upon this point, and it will require extended and skillful, as well as patient, investigation, in the field of Prof. Henry's labors, to furnish what is needed. What we have learned indicates that this increase does occur, and that its amount is very great.

19. The simple increase of cohesive force, where the distances between the molecules are still so immense in comparison with the magnitudes of those molecules, would not be expected to give increased elasticity of volume. On the contrary, during the change from the gaseous state the loss of elasticity of volume has been a marked characteristic.

(It is considered by some philosophers to be well ascertained that the radius of a molecular action is less than one five-millionth of an

inch in some cases,* and that it probably does not equal one two-thousandth of an inch in any in instance.† At least one writer considers that the molecule has an orbital radius not exceeding one two-thousand five hundred millionths of an inch.‡ The existence of animal organisms as small as one two hundred and fifty millionths of an inch in length indicate that even these figures are not probably too small.)

20. An unavoidable inference from the language of authorities most frequently quoted is, that elasticity of form—the quality of which the so-called elasticity and the resilience of solids is a consequence—results from the existence of a property in solid matter by which change of distance between molecules may occur to a marked extent without rupture.

This, if true, would indicate elasticity of form to vary with elasticity of volume.

This, we should infer, may be a mistake, the elasticity of volume being probably less in the solid than in the liquid, while elasticity of form is absent in the latter.

If it be the fact that the elasticity of form, and the resilience of solids are not due to elasticity of volume, primarily, we are justified in attributing them to the property of pliability, produced by the comparatively wide range of intermolecular movement permitted by the force of polarity. In examples of great elasticity, it may have an intensity, small in comparison with that of the other forces acting in the mass, and, at the same time, it, or the cohesive force, or both, may vary at a less than ordinary rate with a given change of distance.

21. We have followed what can be considered as scarcely more than a train of hypotheses, but it is evident that the faint light which has been thrown upon the subject exhibits, at least, a probability that they approximate with some degree of closeness to the truth.

We may deduce from what has been stated, finally, that it is extremely probable that the contraction in volume, of a solid, by approximation of molecules, will increase the absolute strength, while decreasing the viscosity of the body, and, as a consequence, diminishing the resilience, by contracting the elastic limits. The mass might have a higher modulus of elasticity, and higher tenacity, but would more readily yield under a shock or a blow.

* Wartman. † Robison. ‡ Gaudin.

22. We should expect these changes in metals to be most marked within ordinary limits of temperature, in the cases of those metals which have lowest temperatures of solidification, since, in such examples, the complete change from absolute mobility to perfect rigidity is comprised within the least range of temperature.

23. All other things being equal, since lowering the temperature reduces the mobility of particles, and increases the viscosity of the metal, we should anticipate that the greater toughness of the material at the higher temperature, while in the solid state, would not only exhibit itself in a greater resilience, but would also modify the character of the fracture, when ruptured by external force, making it less "short" and glass-like—wherever the substance possessed any thing of the characteristics illustrated by Coulomb's experiments, noted above—at a high, than at a low heat. The fracture would be expected to appear "fibrous" and "thready" when, as in ordinary wrought iron, foreign substances present or varying quality of metal should produce in adjacent parts unequal "drawing down" at the higher temperature.

24. Where, as in iron, the change from the liquid condition through the pasty, semi-fluid welding state, to the condition of comparative brittleness at ordinary temperatures, has been a somewhat regular one, it would be anticipated that the change might continue with still further decline in temperature. It would not appear unlikely that such change might progress indefinitely, or until resilience was absolutely destroyed by the approximation of molecules, and the coincident fixity due to a maximum intensity of polarity.

Where the body has sensible viscosity and considerable resilience it would be expected that, if broken suddenly, as by a quick jerk its fracture would be complete before the particles, retarded by inertia and by molecular friction, could have time to shift their positions, while, when slowly broken, a considerable amount of motion might occur before rupture could be completed.

In the former case, the appearance of the break and the diminution of section would be characteristic of tough, and in the latter, they would apparently indicate brittle, material.

25. Such being, not improbably a statement of the general effects of changes of temperature upon matter, it remains for the engineer to determine, by experiment, how fully the most generally useful metal, iron, presents an example of these effects, and how far they are modified by differences of chemical constitution and of physical

The most interesting and instructive experiments which have yet been made are those of Fairbairn, Kirkaldy, Professor Johnson, of a committee of the Franklin Institute; of a committee appointed by the King of Sweden, of Brockbank, Joule, Sandberg and Spence.

26. Tredgold, the celebrated engineer, whose intelligence and experience have given his published opinions very great weight, believed that any increase of temperature would diminish the tenacity of metals.

Dr. John Percy, on the contrary, with probably the majority of engineers, believe the opposite to be the effect, basing the belief upon the well-known fact that accidents more frequently occur from fracture in cold than in warm weather. So common is this belief, that the statement recently made, that the real effect of decrease of temperature, other things being equal, may be to increase tenacity, has been received with very general distrust.

27. The magnitude of a change of tenacity arising from simple approximation of molecules, and consequent increase of cohesion, could not be expected to be very great, since this change of distance between adjacent particles is but about seven one millionths of its ordinary value for a range of one degree. Were the tenacity to vary as the square of the distance, the consequent variation would be but one and a half per cent., and would be but two per cent. were it to vary, within this range, as the cube of the intermolecular distances for a range of one thousand degrees.

28. In comparing the conclusions deduced by the several experimenters, of whose labors the following is an abstract, some evident misconceptions will be noted, which plainly arise from the very common error of attempting to estimate the strength of materials from experiments in which they are tested by shock, forgetting that a material may be immensely strong, and yet, if brittle, non-resilient, may be readily broken by a blow which would leave uninjured a less tenacious, but more ductile, specimen.

It has evidently been quite unsuspected, by the majority of experimenters, and of writers on this subject, that change of temperature may, while producing an alteration of the cohesion of metals, effect a directly opposite change in its ductility, and that, consequently, the substance may exhibit greater tenacity, and may, therefore, better resist a steady strain, while at the same time its ductility may be so greatly decreased by the same cause as to greatly lessen its resili-

ence, and thus, though stronger, it may be less capable of resisting shocks.

29. A committée of the Franklin Institute, of the State of Pennsylvania, consisting of Professor W. R. Johnson, Benjamin Reeves, and Professor A. D. Bache, were engaged, during a period extending from April, 1832, to January, 1837, in experiments upon the tenacity of iron and of copper, under the varying conditions of ordinary use.

The effect of change of temperature upon those metals was investigated with equal intelligence and thoroughness, and most valuable results were obtained.

30. Upward of one hundred experiments upon copper, at temperatures ranging from the freezing point up to 1000° Fahrenheit, exhibited plainly the fact that a gradual diminution of strength occurs with increase of temperature, and *vice versa*, and that the change is as uniform as the unavoidable irregularities in the structure of the method would allow.

The law of this variation of tenacity, within the limits between which the experiments were made, was found to be closely represented by the formula,

$$D^2 = C\,T^3,$$

i. e., the squares of the diminutions of tenacity vary as the cubes of the observed temperatures measured from the freezing point.

31. The committee, in the course of their exceedingly judicious and complete series of deductions, say:*

"The temperature of no tenacity is generally supposed to be that at which the fusing point of the given substance is placed, and the point of maximum tenacity ought upon general principles to be found at the point at which least heat prevails, that is, at the natural zero, or point of absolute cold, if such a point exists in nature.

"Between these two extremes, it might be supposed that the tenacities of different substances, particularly such as are capable of passing immediately from the solid to the liquid state, would be found to obey certain laws.

"As the total cohesion, at the maximum, would present, to a mechanical agent tending to overcome it, the whole of its resistance, and as, at more elevated temperatures, a part of that tenacity would be overcome by heat, and the rest would be destroyed by the mechanical force, it is evidently a question of experiment to decide what

* Report of Committee, p. 74. Philadelphia: Merrihew & Gunn. 1837.

relation the two forces have to each other, at the temperatures between the two extremes to which we have just alluded.

"To decide the theoretical question, or, in other words, to deduce from the experiments a law which might be expressed in an abstract form, corresponding to all the possible phenomena, would require a state of the materials different from that usually found in commerce or employed in the arts.

"It would also, as we have seen, require a knowledge of that about which philosophers, no less than practical men, are far from being agreed, namely, the point of absolute cold."

32. The committee do not fail to observe that there are indications that the curve, of which their formula is an approximate equation, has, very probably, a point of contrary flexure at a temperature somewhat below the highest at which they were able to experiment, or near the point at which one-half the tenacity of the material is destroyed.

This inflection of the curve, which indicates that no parabolic formula can be made to represent, accurately, the change of tenacity with varying temperature, is very clearly exhibited in the curve laid down from the experiments on the strength of *wrought iron*, which were next made by the committee.

33. These experiments were 73 in number, at temperatures between 212° and 1317° Fahr., and comparisons were made with the strength of the same bars at ordinary temperatures, as determined by 163 experiments.

The bars were generally broken at sections reduced by the file, and the results give but little indication of the effect of change of temperature upon the resilience and extensibility of the metal; but they afford most interesting, accurate and valuable measures of the effect of heat upon tenacity.

34. It was this investigation which first disclosed the remarkable anomaly of the existence of a point in the scale of temperatures, usually, if not invariably, considerably above that of ordinary temperature, at which the metal exhibits a maximum of tenacity.

34. By heating a number of bars to 572° F., which was found to be very nearly the average temperature of maximum strength, and breaking them at that temperature, it was found that a mean of experiments, on the best qualities of rolled iron, gave this maximum as 15·17 per cent. higher than the tenacity of the same samples at ordinary temperatures.*

* Report of Committee, p. 213.

The irregularity of structure of specimens tested was found to cause an irregular variation of strength amounting to 10 per cent.

35. Taking 80° Fahr. as a standard temperature, the committee discovered that the fifth power of the diminution of tenacity from the maximum, determined as just stated, varied as the thirteenth power of the temperature above 80° Fahr.,* or

$$D^5 = C\,(T - 80°)^{13},$$

where D = diminution of tenacity, T = temperature, C = a constant.

At the temperature of about 400° and 1200°, points of departure from the curve took place as already stated, the deviation from the law expressed by the formula becoming quite marked.

35. The committee made a series of experiments upon the effect of annealing in altering the tenacity of the metal.

They found no measurable change in specific gravity, except with specimens which had been hammer-hardened. The tenacity was diminished to an extent which follows very closely the order of temperature at which annealing was performed, and this loss varied from 2½ per cent., when annealing was performed at low temperature, to 46 per cent., when the metal was annealed from a bright welding heat.

The result seems quite variable, but, at about 1100°, the losses had a mean value of about 15 per cent., while, at a welding heat, they averaged nearly 25 per cent.

In testing old boiler plate, a loss was supposed to have been proven, which was attributed to this cause, and which amounted to about 6 per cent.

Unfortunately, the experiments of the committee do not afford the data requisite for determining the resilience of these specimens, and we are unable to learn whether the observed depreciation of strength was accompanied, as we should expect, by an increase of ductility.

36. No experiments were made at temperatures less than 32°, and it remained for further research to determine the behavior of iron at exceptionally low temperatures. The work of the committee was most skillfully performed, and most conscientiously recorded and reported. Together with the equally exhaustive and thorough work of the full committee on steam boiler explosions, of which this was a part, it

* Report of Committee, p. 218.

affords most valuable and reliable additions to our experimental knowledge.

These were the first experiments ever made on an extended scale, and the determination of the area of fractured section, the measurement of elasticity, of latent heat, specific heat, the conducting power, and other properties of iron and copper, were made with much greater care than could have been expected at that early period. The committee were engaged in the work nearly five years, and the expenses incurred were defrayed by the United States Treasury Department.

37. A somewhat similar series of experiments were made by Sir Wm. Fairbairn upon rolled iron,* and the same behavior was noted, under varying temperatures, as was so well shown by the earlier researches of the committee of the Franklin Institute.

The tenacity of Staffordshire boiler plate was examined at temperatures varying from °0 Fahr. to a dull red heat—probably 1000° Fahr.

This iron is not of high quality, and some marked deviations were observed from the general direction of alteration of strength.

The tenacity of the specimens gradually increased, as the temperatures rose from 60° to 395° F., and thence diminished, until, at a red heat, the strength became reduced to the extent of 25 per cent.

The tenacity recorded at 0° F. was, however, 6 per cent. greater than the *mean* noted at any other observed higher temperatures, but not greater than that of individual specimens.

38. Other experiments were made upon rivet iron, which was necessarily of better quality than the Staffordshire plate.

The tabular statement of the results shows a gradual and quite regular increase of tenacity from 60° to 325° F., the strength being given at 68,816 and 84,046 pounds per square inch at those points respectively—a difference of 30 per cent. The tenacity then diminished as temperature rose, becoming reduced to 35,000 pounds per square inch at a red heat.

The strength of 30° F. was slightly greater than at ordinary temperatures, the figure given being 63,238 pounds per square inch.

39. Experimeuts made by Fairbairn on the effect of temperature upon cast iron give less uniform, but still instructive, results.†

With No. 3 iron very unsatisfactory and contradictory results were

* British Association Report, 1856.

† British Association Report, vol. 6, 1837.

obtained, in consequence of the irregular character of its structure and chemical constitutions.

Coed-Talon iron No. 2 exhibited continual decrease of transverse strength as the temperatures increased. Both cold and hot blast irons were experimented upon, at temperatures ranging from 26° to 190° Fahr. with the following results:

Cold blast, at 26° and 190°, decreased in strength in the proportion of 874 to 743. Hot blast, at 21° and at 190°, decreased in strength in the ratio of 811 to 731.

It should be remarked that these experiments were made in the early days of hot blast, when the differences in the character of hot and of cold blast iron were more marked than at a later date, when the management of the former had become generally, and more perfectly understood.

40. Mr. Fairbairn remarks:* "On the whole, we may infer that cast-iron, of average quality, loses strength, when heated beyond a mean temperature of 120°, and that it becomes insecure at the freezing point, or under 32° Fahr."

He supposed that the fact that, in some experiments, he found No. 3 iron to increase in strength with rising temperature, is due to its great "irregularity and rigidity."

He also remarks† that "The infusion of heat into a metallic substance may render it more ductile and probably less rigid in its nature, and I apprehend it will be found weaker and less secure under the effects of a heavy strain."

41. The experiments of Roebling, referred to in his report to the officers of the Niagara Falls Suspension Bridge Co., in 1860, do not throw much light upon the question under consideration.

Mr. Roebling's remark that metal, of as good quality as that upon which he experimented, would be "safe at the North pole,"‡ may justify the inference that he supposed that such iron would at least not lose tenacity when very cold.

(To be continued.)

* On the Application of Cast and Wrought Iron to Building Purposes: London, 1844, p. 66.

† Journal Franklin Institute, 1840, vol. 25, p. 58.

‡ Journal Franklin Institute, 1860, vol. 40, p. 361.

NICKEL AND ITS USES IN THE ARTS, COINAGE AND NICKEL PLATING.

By Dr. Lewis Feuchtwanger.

(Continued from page 140.)

During the suspension of specie payment in 1837 in the United States, the writer conceived the idea of proposing to the Government the issue of a German silver cent, and, as an experiment, he issued 1½ millions of such tokens under his own name, with the permission of the Secretary of the Treasury, for the purpose of obtaining popular favor to this metallic currency. His petition to Congress of that year, which was presented to the United States Senate by Mr. Benton, and to the House of Representatives by John Quincy Adams, with highly flattering encomiums, was referred to the United States mint for report; this report was unfavorable, the director giving some very frivolous reasons, as received from the chemist; but the same individual, while smelter of the mint, took, twenty years later, the opportunity of recommending a nickel compound as a one-cent currency, which, however, did not find much favor in the country, as the coin was not white, and became dirty yellow when in circulation for a month. But 12 per cent. nickel was used in the composition, not by any means sufficient to whiten the copper, while the writer's token, now of thirty-six years' standing, looks at present more like sterling silver than the best American coin. All the numismatic works of this and other countries have adjudged to the writer the palm for his ingenious improvement in the currency.

The nickel coinage.—After the introduction into the United States of the *one cent* coin, which really was a failure, the Belgian and Swiss Governments passed laws in 1860 for issuing a nickel currency—the first to the amount of four millions of dollars, of the denominations of 20 centimes (4 cents), of 10 centimes (2 cents), and 5 centimes (1 cent); while Switzerland issued a German silver coin of similar denominations to the amount of one million of dollars. The United States had coined one million of dollars in the one cent coin already in circulation. The United States Congress wss induced, in 1867, to pass a law for issuing a five cent nickel coin, to consist of 25 per cent. nickel and 75 per cent. copper in place of 12 per cent. nickel and 88 copper. This latter redeemed its honor, for the coin looks really fine, and the late law passed will give in future a respectable small nickel currency of one, three, five and ten cents, of the following weight:

1 cent	to weigh	20	grains.
3 "	"	30	"
5 "	"	50	"
10 "	"	100	"

Instead of five millions of dollars in value of the other nickel currency in circulation in 1868, there will be twenty million dollars of the value of the present nickel coinage in the United States.

The annual production of metallic nickel in the world has been estimated by Mr. Wharton as follows:

England produces	700,000	lbs.
Germany "	500,000	"
Sweden "	50,000	"
United States produces	50,000	"

Which is but 1,300,000 lbs., of which the coinage of the mints in Belgium, Switzerland and the United States absorbs at least 200,000 lbs. per annum, and not less than 1,000,000 lbs. is used for the manufacture of German silver ware, which would leave 100,000 lbs. for the new branch of industry—the nickel plating. The German silver which has been worked for the last thirty years into spoons, forks, tea sets, and many innumerable articles, many of which are plated over with silver, must be of the value of from forty to fifty millions, derived from nickel. This metal forms the basis for a future important revenue in this country, for, with the increased consumption of nickel either as coin, German silver, or plated nickel ware, we diminish the quantity of silver in that channel, and leave the surplus to come back into the general circulation.

Nickel Plating.—An important branch of industry has been in practice in the United States for the last few years only, although it was recommended by Alfred Smee, in his "Elements of Electro-Metallurgy," in 1852, who, in page 193, speaks of nickel in the following words:

"Nickel is the last in the list of noble metals, being the most ignoble of that class. The nitrate and sulphate of nickel, the ammonio-nitrate and sulphate of nickel, the nickelo-cyanide of potassium, but especially the chloride of nickel, require consideration. The nitrate of nickel is very soluble, but the metal has no great inclination to be precipitated, for the hydrogen appears rather to prefer being evolved than to reduce the metal. The sulphate of nickel is also used as a double salt, and the metal is reduced more readily from it than from the nitrate. It is best reduced by the compound battery process with a platinum positive pole, though a nickel positive pole may be em-

ployed. The solution of either nitrate or sulphate combined with alkalies, those of ammonia deserving the preference, ought to be as strong as possible. The chloride of nickel forms an excellent material for precipitation, by means of a nickel positive pole with one or two batteries. The nickel so deposited has a peculiar white, brilliant lustre, looking almost like glass. This deposit is so beautiful, when removed from the negative pole, that it forms a great contrast to the common nickel metal, and no person would ever suppose that there was any similarity of composition between that substance, still less identity. For practical purposes the chloride is first, and next to it is the sulphate for the regaline deposit."

It has been ascertained that the nickel-plated ware lasts four times as long as the silver-plated, and is four times cheaper than silver-plating, nor does it tarnish as easily as silver; for sulphuretted hydrogen acts readily on silver, and not on nickel. We see now everywhere the utensils for the house, ship, harness and carriage trimmings, dental, surgical, philosophical and musical instruments, reflectors, sadirons, stair-rods, guns and pistols, many models requiring protection from the oxidizing or corroding action of the air or water, with a vast number of articles in daily use, as also the polished iron and brass materials used on board of a ship, where the salt water atmosphere is so liable to corrode, and machinery of every description plated with nickel. There was a capstan so plated, at the late fair of the American Institute, which the writer conceived to be injudicious, for the reason that nickel is magnetic, and should not be employed near the compass. The batteries used in the nickel-plating are of various inventors, such as the Wollaston, Daniell, Grove, Bunson and Smee batteries.

Daniell's battery consists of a box of eight inches to two feet in height and four inches in diameter. The outer vessel is to be made of copper, of which the external part may be painted, as it plays no part in generating electricity, while the inner remains uncoated. Into this cylinder a solution of sulphate of copper is to be poured, instead of the dilute acid used in other batteries. In order to separate the zinc cylinder from the sulphate of copper, it rests in a porous cup, which contains the zinc surrounded by dilute sulphuric acid. As soon as contact is made the zinc is dissolved, and sulphate of zinc is retained in the inner part of the vessel; whilst, instead of the hydrogen being evolved at the negative metal, it reduces the copper from the sulphate of copper. The more porous the inner vessel is, the greater is the quantity of electricity developed; therefore coarse canvas or

porous earthen tubes are now employed instead of the bladder. Daniell used for his positive metal cast zinc rods, which he amalgamated. But zinc cylinders are indispensable, and the porous vessel must not touch the battery plates. This battery has the power of generating exactly the same amount of electricity for a long time, and is celebrated for its effects.

Grove's battery employs platinum as the negative metal, and has in the inner porous cells strong nitric acid, while the outer cell of the zinc cylinder contains dilute sulphuric or muriatic acid; the nitric acid, when employed, is decomposed by the hydrogen, and deutoxide of nitrogen is evolved, which is converted into nitrous acid when coming into contact with atmospheric air.

This battery is remarkable for its intensity. Four such single batteries are sufficient for large operations in electroplating. The only drawback to its general uses is the nitrous acid fumes, which are very offensive; the same fumes also attack the zinc to a considerable extent. While Daniell's battery has its good side, it has also the disadvantage of varying the quantity of electricity by altering the wires as to size and length, as also the labor to set a Daniell's battery in motion; also the trouble and expense in using the porous tubes, and the necessity of continually reamalgamating the plates, and, lastly, the small quantity of fluid which the porous pots contain to dissolve the sulphate of zinc.

In Grove's battery the nitrous acid fumes of the nitric acid battery which are so objectionable have been changed in the application of bichromate of potash, which, in a concentrated state of solution, is put on the negative side of the battery, while dilute sulphuric acid is used on the zinc sides. This latter is dissolved on the outer side of the battery by dilute sulphuric acid, and the bichromate is decomposed at the negative end.

Smee's Chemico-Mechanical Battery.—This battery is the same as Daniell's, but sulphate of copper is replaced by platinum. A small quantity of nitro-muriate is thrown down on the sheet-platinum, previously roughed by sand-paper. The same process may be performed on palladium, silver (roughened by nitric acid), plated copper, iron of every sort, and on charcoal—all with the same good result.

Silver is most generally employed on account of its cheapness, and not undergoing any alteration. The object is to afford a surface to which the hydrogen shall not adhere, but shall be evolved from it. The platinized silver used for this purpose ought to be thick enough to carry the current of electricity, and should be roughened either by

sand-paper or by brushing it over with a little strong nitric acid, so that a frosted appearance is obtained. The silver is then washed and placed in a vessel with dilute sulphuric acid, to which a few drops of nitromuriate of platinum are added; a porous cup is then placed in this vessel, with a few drops of diluted sulphuric acid; into this the zinc is put. Contact being made, the platinum will in a few seconds be thrown down upon the surface of the silver, as a black metallic powder. The operation is now completed and the platinized metal ready for use.

Iron, if prepared in the same manner as silver, may be used for the same purpose, and employed with advantage; all that is required is to rub a little nitromuriate of platinum over it and an immediate deposit of the black powder takes place. The liquid generally adopted to excite this battery is a mixture of 1 part by measure of sulphuric acid and 7 of water, which will be found amply strong for all purposes. Where we desire greater intensity, it can be obtained by the addition of a few drops of nitric acid, but if too much be used, it might attack the silver. The operator will frequently find it advisable to use diluted sulphuric acid, only retaining 1-10th to 1-16th of the pure acid, and adding some acid when the first is exhausted. The zinc, acid and water being severally required to excite the battery, they may be regulated so that they should all be exhausted at once, so that the zinc should neutralize the acid and the resulting sulphate of zinc exactly saturate the water.

In place of platinized silver, the carbon plates, also the chromium plates have been used with decided success for the negative poles.

From what has been stated, it is obvious that Daniell's battery is distinguished for its constancy, Grove's for its intensity, and Smee's for cheapness and simplicity in the development of electricity. It is of great importance to know which battery yields the greatest amount of galvanic fluid at the smallest cost, least labor and greatest convenience. The main tendency of the three described batteries lies in the action of zinc upon water, and when, in connection with acid, to form sulphate of zinc.

Bunsen's battery depends upon the application of carbon cylinders and forms also a convenient and economical apparatus.

The platinized silver plates of Smee's battery are now replaced by carbon plates, as also by chrome plates which are said to form a very constant battery; while offering a greater surface for the decomposition of the metallic salt, they must prove more economical.

Coating with Nickel.—Napier, in his Manual of Electro-Metal-

lurgy, speaks of nickel coating; that it is very easily deposited and may be prepared for this purpose by dissolving it in nitric acid, then adding cyanide of potassium to precipitate the metal, after which the precipitate is washed and dissolved by the addition of more cyanide of potassium. The cyanide of potash has proved unsuitable for nickel plating; he says that he coated articles with nickel in 1847, and up to 1853 they still retained their brilliancy and continued untarnished. Napier gives also the following practical instruction for plating, in the following words: It is indispensable that the battery should be so arranged that the quantity of electricity generated should correspond with the surface of the articles to be coated, and that the intensity should bear reference to the state of the solution, that is to say, that the quantity should be sufficient to give the required coating of metal in a given time, and the intensity such as to cause the electricity to pass through the solution to the articles. It is also essential that the plates of metal forming the positive pole with the solution should be of corresponding surface to the articles to be coated, and face them on both sides. A rough idea may be given here of a plating vessel which is about 6½ feet in length by 33 inches in breadth and 33 inches in depth, and contains from 200 to 250 gallons of solution; the silver or nickel plates serving as electrodes. Two battery troughs are arranged so as two consist of six batteries of three pair intensity. The zinc plates, immersed in the acid from which electricity is disengaged and the electrode exposed to the articles receiving the deposit, being in proportion.

The vat should contain the solution with the battery having the zinc pole inverted, connecting with rods upon which the articles are to be suspended with wires, and a copper pole is then connected with the electrode. So soon as the articles which are connected with the negative pole of the battery and the electrode connected with the positive pole are immersed in the solution, the galvanic circuit is completed.

To ascertain the amount of metal deposited, it is well to weigh such articles carefully before and after the operation is completed.

Description of an extensive establishment of nickel plating in actual operation for saddlery hardware, sadirons, bits and turrets, and where 500 lbs. material are daily plated, finished and brought to market:

1. It consists of a lage wooden box, which is five feet six inches long, fourteen inches deep, and two feet wide, lined with asphaltum varnish so as to be perfectly tight.

2. The capacity of the box is seventy gallons liquid, consisting of hot water, in which three-quarters of a pound of the double salt of sulphate of nickel and ammonia to each gallon are dissolved.

This vat is connected by wires with (3) a *Smee battery*, consisting of six zinc plates, 9×10 inches, which are previously well amalgamated with mercury, (4) and six carbon plates, likewise 9×10 inches. This box may be lined with lead and must contain ten gallons of water, to which twenty ounces of oil of vitriol are to be added. The carbon plates are now put between each zinc plate, and will keep up the evolution of hydrogen gas as soon as put in connection; it will remain in active operation for two weeks, while the zinc plates need no re-amalgamation for four months.

5. Copper or brass wire is stretched across the decomposing or plating vat, for suspending the various articles to be plated, which, according to the power of the battery, takes from six to ten hours, but the average will be eight hours. It is fully understood that the ware must be perfectly clean, free from grease or dust before introducing them into (6) the bath. After being taken out from the plating liquid, the articles are washed off with hot water and polished on a cloth buff with crocus, rouge, Vienna lime or other polishing powder and oil.

The expense attending the nickel-plating is quite inconsiderable; spoons and forks may be coated completely with nickel for 25 cents per doz.; turrets or check holders, wheel hubs, large bits, and other saddlery trimmings, for 30 cents per doz.; a sadiron, weighing five pounds can be plated for four cents.

The operation is constantly going on; as soon as one set is sufficiently coated it is removed and replaced by another.

The main condition of nickel-plating lies in these points: 1, to have the solution always kept neutral, it is necessary to test frequently the liquid by means of litmus paper, and if the same indicates a prevalence of acid, to add sufficient caustic ammonia to make the liquor perfectly neutral; also to replace occasionally the consumed salts; 2, to have the materials to be plated always perfectly clean, which, if the goods are of iron, can be done by dipping them in a mixture of muriatic acid and water; the least scratches will prevent a complete coating.

Number 30 brass wire for small articles, and number 16 wire for larger copper articles, are used for suspending the ware.

The chloride of nickel and ammonia is much used for plating, requiring but four ounces of the salt to one gallon of water.

A simple nickel-plating apparatus, likewise in full operation, may also be described, as very satisfactory results are daily realized: 1, a bath or vat containing the usual nickel solution of double salt, three-quarters of a pound to the gallon of hot water; five gallons is applied to the porous cell which contains the amalgamated zinc pole three inches broad, seven inches deep, and seven inches long, but touching within one-half of an inch all around from the cell. The copper wire is connected, to hold suspended the articles, such as faucets, pistols, or other ware to be plated with nickel; the operation goes on at once and deposits the metallic nickel from its solutions in the space of three to four hours.

In a synopsis of Adams' claim of nickel-plating for which he obtained four patents, I find that he bases the one of August 3, 1869, on a solution of the double sulphate of nickel and ammonia, and of a solution of the double chloride of nickel and ammonia; the patent, March 22, 1870, on the solution of the double sulphate of nickel and magnesia; and in that of May 25, 1870, for a solution of the double sulphate of nickel and ammonia; while in his last patent of March 11, 1873, he claims a solution of either of the soluble salts of nickel, which must be free from the presence of potash, soda, lime, alumina and nitric acid, or either of them, and free from acid and alkaline reaction, or from either. It appears, therefore, that they are all tending to prove the character of the solutions he uses for depositing the nickel, which, however, have been very clearly described by George Gore, in 1855, and the application of the double salts are published by Smee. Booth's Dictionary, for 1852, speaks of a nickel battery consisting of either the nitrate or sulphate of nickel and ammonia being used for plating. The preparation of pure metallic nickel, whether from the ore or by recasting of such granular nickel, as is manufactured in Camden, N. J., or as is imported from the English and German manufactories, is generally considered to be a known metallurgical process. Whether the nickel metal contains some carbon or iron, if used as anode, matters little, for it does not affect at all the operation of plating.

Mr. Bequerel states that any one may apply the process which Mr. Adams has patented, without any infringement, as potash in no way affects injuriously the deposition of nickel, the double sulphate of nickel and potassa as well as the double sulphate of nickel and ammonia can easily be applied; while the special feature of Mr. Adams' patent, consists in the exclusion of the smallest quantity of potash, soda, or other alkaline earth from the bath, containing the nickelizing

preparation, pure double chloride of nickel and ammonium or the perfectly pure sulphate of nickel and ammonia may safely be employed.

Nagel's process for electroplating with nickel or cobalt is likewise based upon applying the double salts of sulphate of nickel and ammonia or double salts of sulphate of cobalt and ammonia with the platinum positive pole. It consists in taking 400 parts of the sulphate of nickel and 200 parts ammonia, dissolved in 6000 parts of hot water and the ammonia of 0·909 spec. gravity, heated to 100° F., and if cobalt, but 138 parts of the sulphate of double salt are employed.

Mr. Beardslee, who is unquestionably the veteran in nickle plating in the United States, informs the author that ever since 1858, he has coated metals with electric currents; that he found the chloride of nickel with a certain quantity of ammonia to be of great service.

He attributes any failures in depositing nickel to the following requirements:

1. Nickel must have a perfectly uniform and unchanging current of electricity; a Smee battery, with a chromium negative plate, gives a powerful and constant current of electricity.

2. The nickel solutions with the chloride solutions may work better with acid instead of alkaline reaction; he quotes, as instances, that he had 2000 gallons of nickel solutions since 1868 and 1869, in constant use without any addition, but have been corrected from time to time in order to give them an acid reaction, as the tendency in working is to become alkaline.

The author begs, however, to close this pamphlet and the subject of nickel plating, by remarking that sulphate of nickel and ammonia will work better if kept under an alkaline reaction.

The following remarks, given to the author by Mr. Beardslee, are of much importance to those who wish to be fully posted:

He uses two cells of the chromium negative plate battery; the amount of battery power required for a given quantity of work to be done should be in zinc surface, equal to the surface to be quoted.

The surface of the nickel anode should in no case be less than the surface to be coated. The anode surface for a nickel solution may be much greater than the surface to be coated; and more and better work will be the result.

For a nickel solution of 40 gallons, 10 anodes of 6×12 inches are required, and in proportion to the greater or less quantity of gallons.

By estimating 7½ gallons to each cubic foot, we can determine the amount of solution that will be required for a vat of any given size.

The nickel anodes are connected with the negative plate of the battery, which may be either the chromium or carbon plates; the articles to be coated are connected with the zinc pole of the battery.

In one gallon of the nickel solution, a nickel anode of 4×6 inches is employed for coating small articles from two one gallon cells of the chromium negative plate battery.

Stolba's method of nickel-plating by means of chloride of zinc, has lately been introduced for coating iron, steel, copper, brass, zinc or lead. He recommends the chloride or sulphate of nickel as simple salts (which need not be chemically pure).

To a portion of chloride of zinc twice the volume of water is added, the mixture is then boiled, and hydrochloric acid is slowly added, until the precipitate formed by the dilution redissolves again. A very little zinc powder is added, and in a few minutes the vessel is coated with zinc wherever the liquid is in contact with it. Nickel salt is then added to it in sufficient quantity to impart a green tint to liquid. The articles to be plated are then introduced, along with a few cuttings of zinc, making as many points of contact as possible; the mixture is to be boiled for about 15 minutes, when the coating is complete.

SHAW'S GUNPOWDER HAMMER.*

Philadelphia, Pa., July 15th, 1873.

To the Editor of the Journal of Franklin Institute:

SIR:—In the issue of your valuable journal dated July, 1873, you publish an article, signed by S. R. Probasco, and reported as being part of the proceedings of the American Society of Civil Engineers at the meeting of March 5th, 1873, condemning my invention.

It is held that a patented invention is private property, and that an unfair public report on the same is incompatible with the rules of any well regulated scientific society, and I cannot learn that the American Society of Civil Engineers have in any way sanctioned the opinions expressed in said article.

Had the writer of that article intended a fair report, as information before an honorable body of scientific gentlemen, such as the American Society of Civil Engineers, he could have been considerably aided by consulting the writer, with whom he was personally

* The paper referred to by Mr. Shaw was received, amongst other matter for publication, from the Secretary of the Am. Soc. Civ. Eng., since which we learn that said paper of Mr. Probasco, was an *unofficinal* abstract of a communication made to that Society.—ED.

acquainted, but to whom he gave not the slightest hint of his intentions; or by consultation with the foreman or operatives of several machines, working highly satisfactory, within fifty minutes of his residence. Or, if he was desirous of taking upon himself any labor to investigate the capability of the driver, he might have consulted the published reports of careful and accurate experiments, signed by the highest and most intelligent engineers in the country, viz.: W. W. W. Wood, Engineer in Chief U. S. Navy, F. C. Prindell, Chief Engineer Philadelphia Navy Yard, H. Hoff, of the Eagle Iron Works; or he might have consulted the published reports of the committee of the Franklin Institute of Pennsylvania, who had the matter in hand for a period of several months, and who recommended the Scott Legacy Medal for this invention, said medal being the highest honor they could confer. This committee was composed of the ablest talent in the Institute, viz.: Prof. Morton, President of Stevens Institute, Hoboken, N. J., John C. Cresson, Chief Engineer Fairmount Park, John Agnew (lately deceased), the great fire engine builder, and E. Longstreth, superintendant and partner of the largest locomotive works in the world (located in this city). All these reports seem to have been thrown aside, or not noticed by the author of the article in question, who has selected a badly managed machine, entirely to light for its work, and employed upon the hardest soil known to pile drivers.

Mr. Probasco's statements differ from my own personal observation. For I saw *that* machine drive 10 piles in 3 hours upon that identical work, with an average of 140 blows per pile, using 1½ oz. charges of powder per blow. These piles could have been driven by 20 blows of the gunpowder hammer had it been constructed with a view to the work to be performed, and Mr. Probasco was so informed, and is fully aware of my dissatisfaction with that machine, placed under such disadvantageous circumstances, and that I condemned *that* machine for *that* work. He might with equal propriety take a locomotive off the track and notice its working as a sample of its usefulness upon the rail.

I give below the workings of the gunpowder hammer upon the various soils. The reader will notice in Major Turpin's letter (a highly educated engineer) the very hard driving encountered, and his statement that he has driven as many piles with the gunpowder hammer in 26 hours as he could drive with the steam hammer in 20 working days. The average driving time for ordinary driving (25 feet driven) is one minute per pile. The average cost for powder is

15 cents per pile, and the average blows 8 per pile. The same number of hands are required as for a steam hammer.

The United States Gunpowder Pile Driver Company of Philadelphia, Pennsylvania, owners of the patent gunpowder hammer, offered to place a proper size machine upon the work at Parsonage Lake and guarantee to drive those same piles through that very difficult conglomerate soil in a rapid and satisfactory manner; and the contractor of the pile driving portion told me he would place there the kind of machine I recommended if the parties wishing the piles driven would pay a living price for the work; otherwise he would throw up the job—which was the final result. Hence there was no chance for the company to place a properly proportioned machine upon that work. The machine quoted by Mr. Probasco was condemned by the writer in the most emphatic terms for that work.

The following reports show the actual work done by some of our earliest constructed machines. Since which time we have added several improvements which increases their efficiency. Since writing the above, I have been handed by my friend, Mr. Holroyde, a letter from the Secretary of the American Society of Civil Engineers, stating that Mr. Probasco's published report is an unofficial abstract, and unauthorized by that Society.

Extracts from F. C. Prindell's report of pile driving at League Island, show that the average blows of the gunpowder hammer per pile is 5·2. The piles being driven an average of 19·4 feet, with an average of 8·2 ounces of powder per pile. And that the largest number driven in one hour is 12 piles. And that on experimental trial the pile was driven an average of six times greater distance per blow with the gunpowder hammer as compared to ordinary drop hammer of same weight, and falling the same distance.

THOMAS SHAW.

[*Copy of F. C. Prindell's Letter.*]

CIVIL ENGINEER'S OFFICE, U. S. Naval Station,
League Island, July 19th, 1873.

The Gunpowder Pile Driving Co. of the United States:

GENTLEMEN—In response to your inquiry of the 16th inst., requesting me to favor you with a statement of the work done by Shaw's Gunpowder Pile Driver under my supervision here, as well as my opinion of its merits, etc., I would respectfully state that about (2000) two thousand piles have already been driven by this process on the works of improvements at this station, embracing a variety of work, afloat and ashore, and all in so satisfactory a manner that preparations are now in progress for driving several hundred more with it this season.